EPRI

Nova Scotia Tidal In-Stream Energy Conversion (TISEC): Survey and Characterization of Potential Project Sites

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Phase:	1 – Project Definition Study
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Author:	George Hagerman
Co-authors:	Gordon Fader, Greg Carlin, Roger Bedard
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Organization(s) that prepared this document

Electric Power research Institute (Roger Bedard)

Virginia Polytechnic Institute and State University (George Hagerman)

Atlantic Marine Geological Consulting, Ltd. (Gordon Fader)

Nova Scotia Power, Inc.
Bill Richards – Generation, NSPI
Greg Carlin – generation, NSPI
John Charlton - T&D Assets, NSPI
Willard Cameron - Generation Services, NSPI
Bill Ellis - Control Center Operations, NSPI

Table of Contents

1. Executive Summary 3
2. Acronyms and Conventions 4
3. Introduction 5
   3.1. Geological and Oceanographic Setting 5
   3.2. Survey Approach and Organization of Report 7
4. Site Selection Criteria 10
   4.1. Water Depth Requirements 11
   4.2. Turbine Spacing and Projected Area 12
5. Site Characterizations 13
   5.1. Cumberland Basin 16
   5.2. Minas Channel 30
   5.3. Minas Passage 42
   5.4. Cobequid Bay 51
   5.5. Digby Gut 61
   5.6. Petit Passage 69
   5.7. Grand Passage 76
   5.8. Great Bras d'Or Channel 83
6. References 91

Appendix A – The Nova Scotia Power Inc (NSPI) Grid
Appendix B – Nova Scotia Shipyards and Marine Industry

1. Executive Summary

This report provides the basis for selecting the most promising sites for a pilot demonstration project consisting of a single tidal in-stream energy conversion device, or a notional 500 kW array (whichever is smaller) and for a first commercial project, sized to extract 15% of the total peak tidal energy available or having a notional 10 MW capacity, whichever is smaller. Sufficient data are provided to enable the Nova Scotia Provincial Advisory Group to select a single site for a subsequent feasibility-level design, performance analysis and cost estimate for each of these two project sizes.

Eight potential project sites were identified in Nova Scotia that have both flood and ebb peak tidal current surface velocities averaging at least 1.5 m/sec (3 knots). The mean extractable power (15% of the mean total depth-averaged power) at each of these sites is indicated below:

(1) Cumberland Basin – 6.5 MW
(2) Minas Channel – 131 MW
(3) Minas Passage – 166 MW
(4) Cobequid Bay – 6.3 MW
(5) Digby Gut – 4.9 MW
(6) Petit Passage – 9.2 MW
(7) Grand Passage – 6.6 MW
(8) Great Bras d'Or Channel – 1.4 MW

Channel depths, seafloor properties, grid interconnection, maritime infrastructures, and environmental issues are generally satisfactory for all eight sites, with a few notable exceptions, as follows. A thick layer of unconsolidated sediments in the Cumberland Basin could cause problematic foundation installation there. Prohibitively costly distances to interconnect larger projects in Petit and Grand Passages to 69 kV lines on the mainland will constrain the economically developable project sizes at these sites to under a megawatt.

Minas Channel and Minas Passage have 262 to 333 MW of potential installed TISEC capacity (assuming that 80% of the extracted energy can be converted to electric power in a plant with a 40% capacity factor), representing a significant fraction of Nova Scotia Power's existing generating capacity. These are the only tidal in-stream energy conversion sites in North America that have sufficient potential for central generation rather than distributed generation projects.

106-07226/

2. Acronyms and Conventions

CHS	Canadian Hydrographic Service
ECC	Energy Control Centre (a NSPI centre)
EPRI	Electric Power Research Institute
KPH	Kilometers per hour
kV	Kilovolts
kW	Kilowatts (power)
kWh	Kilowatt-hours (energy)
kW/m^2	Power density in kilowatts per square meter of submerged turbine rotor swept area
MCT	Marine Current Turbines (a device developer)
MW	Megawatts (power)
MWh	Megawatt-hours (energy)
NSPI	Nova Scotia Power, Inc
ODI	Ocean Data Inventory
TISEC	Tidal in-stream energy conversion
UNESCO	United Nations Educational, Scientific and Cultural Organization

Throughout this report, the orientation of all maps and aerial photographs taken from directly overhead (*i.e.*, not from an oblique angle) is such that north is the vertical direction toward the top of the page.

3. Introduction

The purpose of this report is to identify and characterize sites in Nova Scotia that have significant development potential for tidal in-stream energy conversion (TISEC). This report provides the basis for selecting the most promising sites for a pilot demonstration project, notionally rated at 500 kW (producing 1,500 MWh annually at 40% capacity factor) and for a first commercial plant, notionally rated at 10 MW (producing 30,000 MWh annually at 40% capacity factor). Sufficient data are provided to enable the Nova Scotia Provincial Advisory Group to select a single site for a subsequent feasibility-level design, performance analysis and cost estimate.

3.1. Geological and Oceanographic Setting

The Gulf of Maine, including the Bay of Fundy, is one of the world's most biologically productive environments. Its marine waters and shoreline habitats host some 2,000 species of plants and animals. The coastlines of Massachusetts, New Hampshire, Maine, New Brunswick, and Nova Scotia make up its western and northern boundaries. As shown in the figure below, Georges and Brown Banks define the seaward edge of the Gulf of Maine, forming a barrier to the North Atlantic Ocean. Between these banks is the Northeast Channel, a deepwater conduit that brings dense, high-salinity, nutrient-rich water from the North Atlantic into the Gulf.

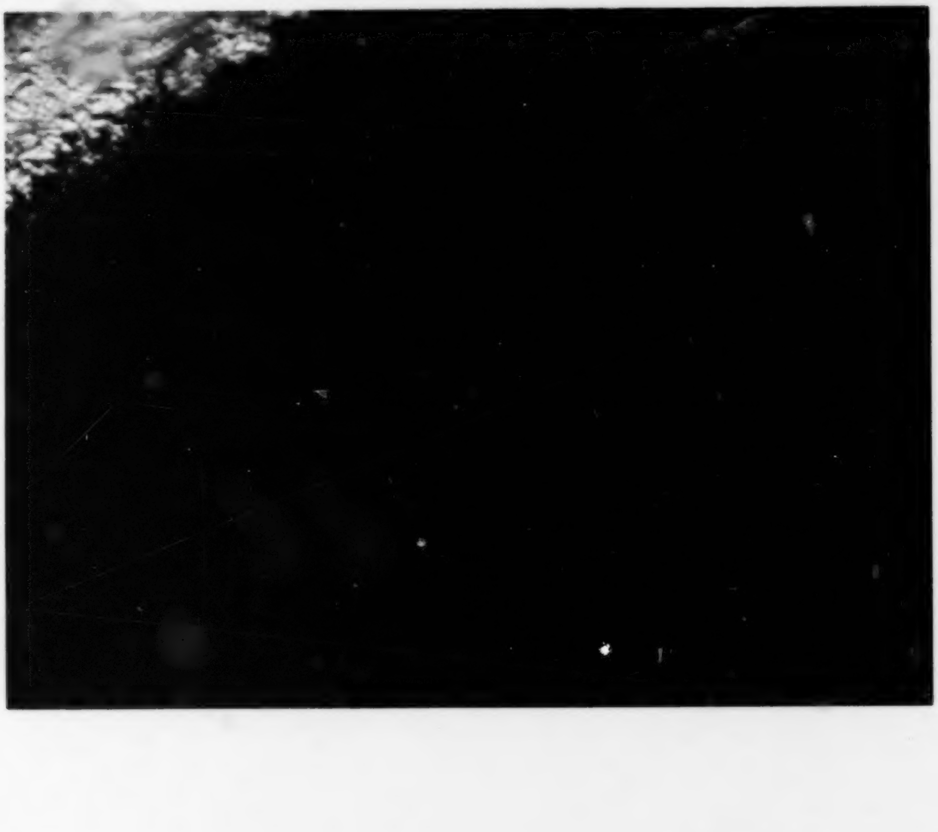


Figure 3.1-1. Three-dimensional rendering of seafloor bathymetry in the Gulf of Maine and Bay of Fundy, with vertical depth exaggerated by a factor of 75 to enhance bottom features. (Source: www.gulfofmaine.org/knowledgebase/aboutthegulf/maps/mapsandphotos.asp)

Tides in the Gulf of Maine and Bay of Fundy are forced by tides in the North Atlantic Ocean rather than directly by the sun and moon. The North Atlantic tide enters the Gulf of Maine via the Northeast Channel and then spreads as a refracted wave across the Gulf (Reference 1). After entering the channel, this wave travels 335 km to reach the shelf edge between Bar Harbor and Jonesport, Maine about three hours after entering the Northeast Channel (Figure 3.1-2, below).

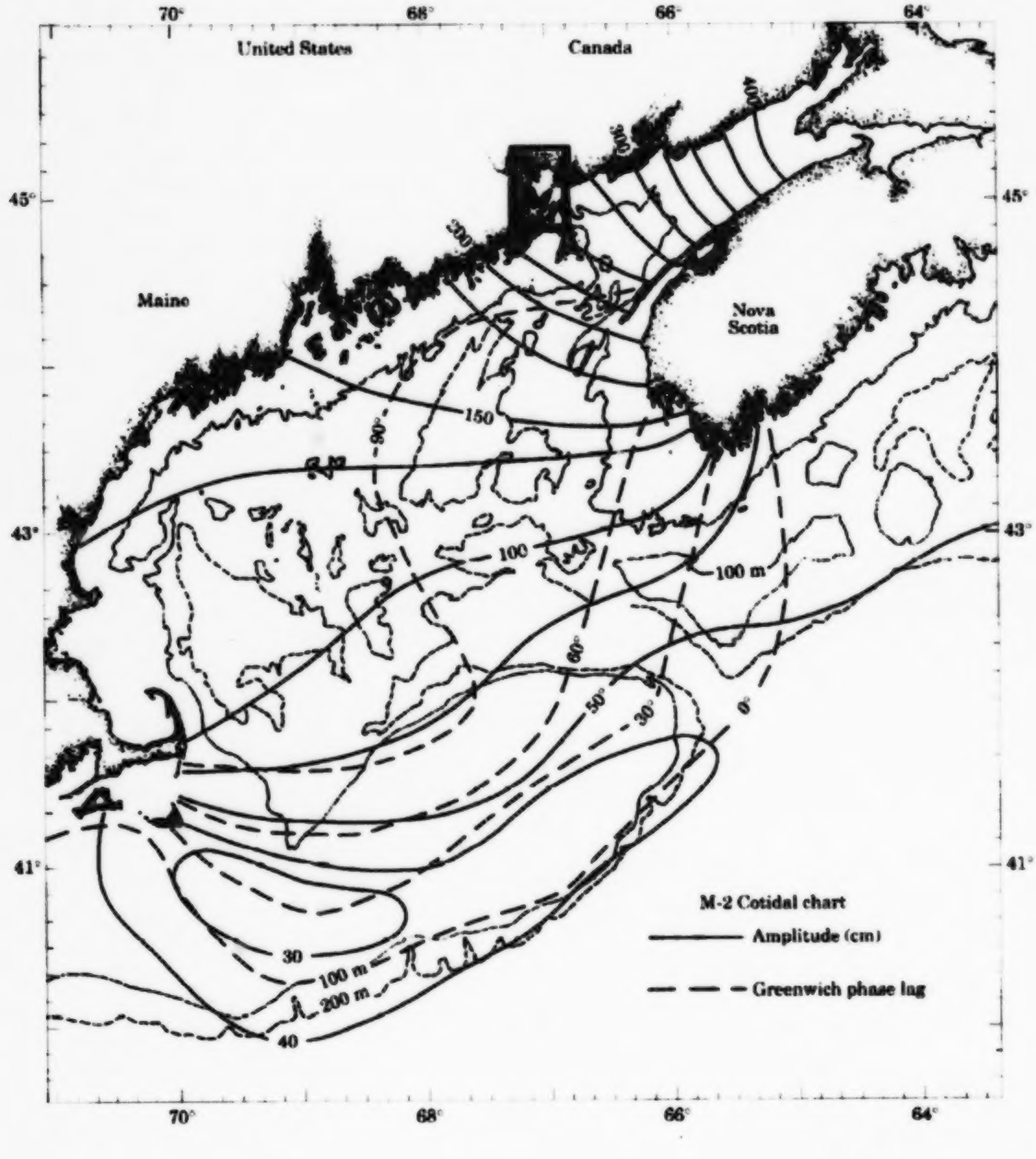
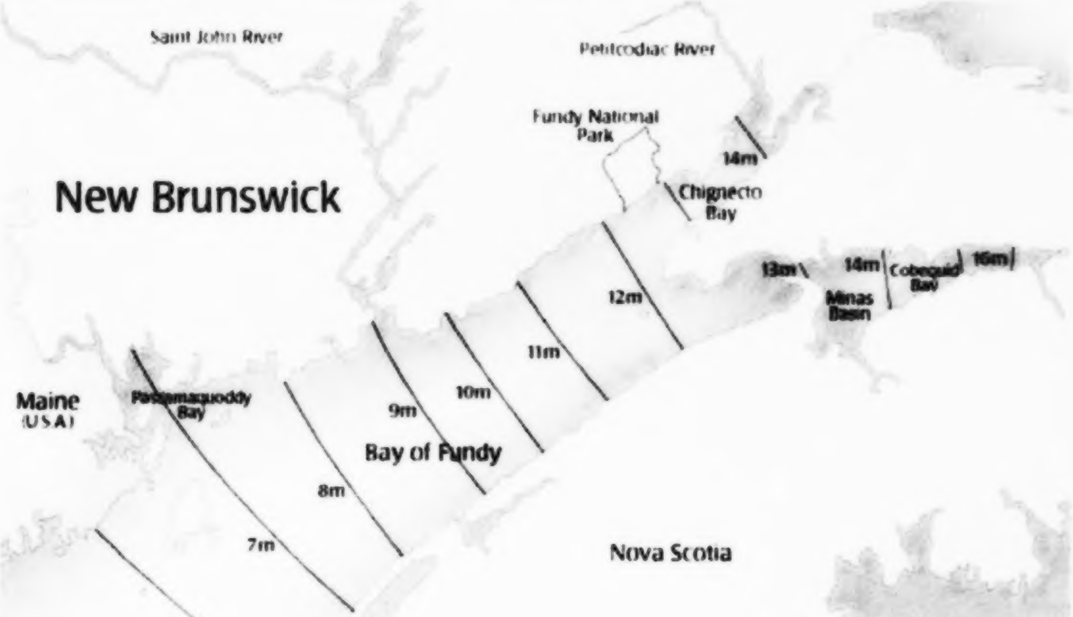

70°
68°
66°
64°
United States
Canada
45°
Maine
Nova Scotia
150
90°
80°
43°
100
100 m
60°
50°
30°
0°
300
330
400
41°
30
100 m
200 m
40
M-2 Cotidal chart
Amplitude (cm)
Greenwich phase lag

Figure 3.1-2. Behavior of the M-2 (principal lunar semi-diurnal) tidal constituent as it progresses across the Gulf of Maine and into the Bay of Fundy. (Source: Reference 2)

The relatively close spacing of the dashed co-tidal lines in Figure 3.1-2 indicate the progressive nature of the North Atlantic tidal wave as it sweeps along the southern coast of Nova Scotia and refracts toward Cape Cod. In the southern bight of the Gulf of Maine and in the Bay of Fundy, however, its behavior is closer to that of a standing wave, with high and low water levels occurring at approximately the same times around the shoreline (except in the Minas Basin, where there is a lag of about an hour).

The average tidal range at the North Atlantic entrance of Northeastern Channel is 0.9 m, increasing to 3.1 m at Bar Harbor. At the mouth of the Bay of Fundy, the average tidal range is about 5 m, increasing dramatically toward the basins at the head of the Bay.

Two phenomena account for this amplification of tidal range. First, the natural period of the semi-enclosed basin that encompasses the Gulf of Maine and Bay of Fundy is about 13 hours, which is very close to the principal lunar semi-diurnal tidal forcing period of 12.4 hours. Second, and of particular importance in the Bay of Fundy, are the effects of shoaling and funneling, which reduce the cross-sectional area of the Bay by a factor of two between Grand Manan Channel at the mouth of the Bay to Saint John, NB, and again by a factor of two near Cape Chignecto, where the Bay of Fundy splits into Minas Channel to the south and Chignecto Bay to the north. Becoming gradually shallower, Chignecto Bay splits further into Shepody Bay and Cumberland Basin. Further shoaling and narrowing within these embayments leads to the highest tidal ranges in the world, as shown in Figure 1.1-3, below.


Saint John River
Petitcodiac River
Fundy National Park
14m
New Brunswick
Chignecto Bay
13m
14m
Cobequid Bay
16m
Minas Basin
12m
11m
10m
9m
Maine (USA)
Passamaquoddy Bay
Bay of Fundy
8m
7m
6m
Nova Scotia
Atlantic Ocean

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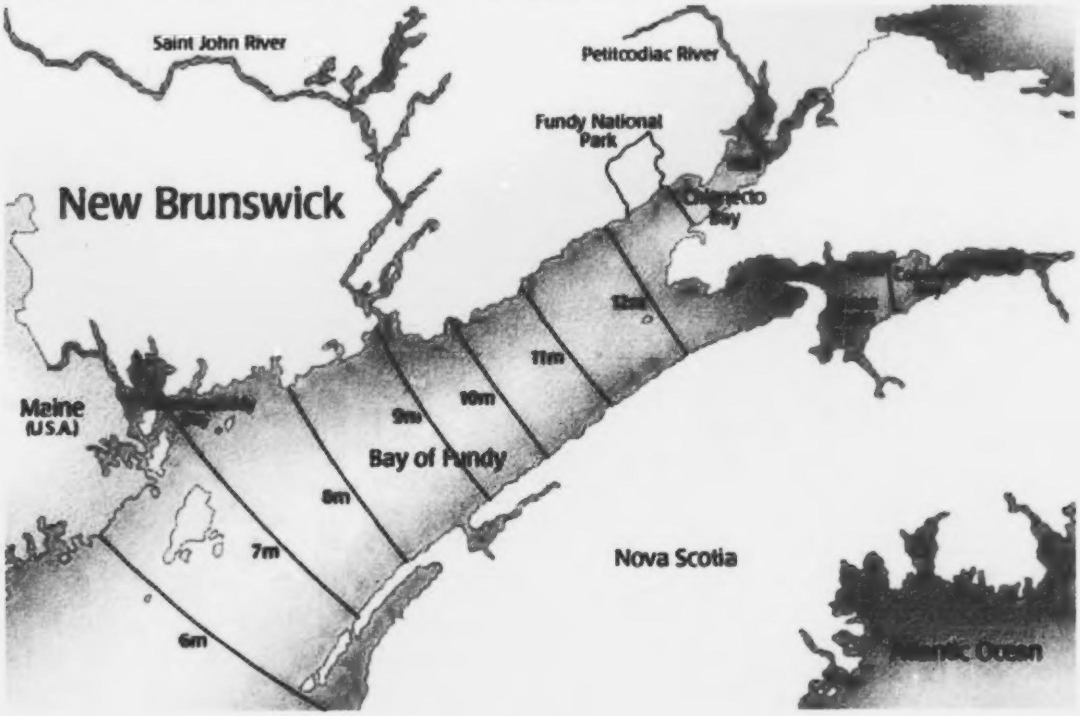


Figure 3.1-3. The Bay of Fundy is 290 km long. Its entrance is 100 km wide and ranges in depth from 120 to 215 m. The effects of shoaling and narrowing increase the tidal range up the Bay at an exponential rate of about 0.35% per km, from 6 m at the entrance to 16 m in Cobequid Bay.

3.2. Survey Approach and Organization of Report

Eight potential tidal in-stream energy project sites were identified in Nova Scotia, based on discussions with various Canadian marine scientists and review of the following references:

- "Classification of Estuaries, Inlets and Coastal Embayments" or CEICE, a tabulation of some of the geographic, oceanographic, and hydrological parameters for 141 coastal embayments in the Bay of Fundy, Scotian Shelf and southern Gulf of St. Lawrence. (Reference 2)
- *Atlas of Tidal Currents, Bay of Fundy and Gulf of Maine*, 1981. Prepared by the Canadian Hydrographic Service. (Reference 3)
- *Canadian Tide and Current Tables, Volume 1, Atlantic Coast and Bay of Fundy*, 2005. (Reference 4)
- *Sailing Directions, Gulf of Maine and Bay of Fundy*, 2001. (Reference 5)

Initial screening was based on peak ebb and flow velocities estimated in References 2, mapped in Reference 3, predicted in Reference 4, or reported in Reference 5. Any site that had both flood and ebb peak velocities averaging at least 1.5 m sec (3 knots) was included in this survey.

Eight potential project sites meeting this criterion are mapped in Figure 1.2-1 and listed below:

(1) Cumberland Basin (potential for a joint New Brunswick-Nova Scotia project)

(2) Minas Channel

(3) Minas Passage

(4) Cobequid Bay

(5) Digby Gut

(6) Petit Passage

(7) Grand Passage

(8) Great Bras d'Or Channel

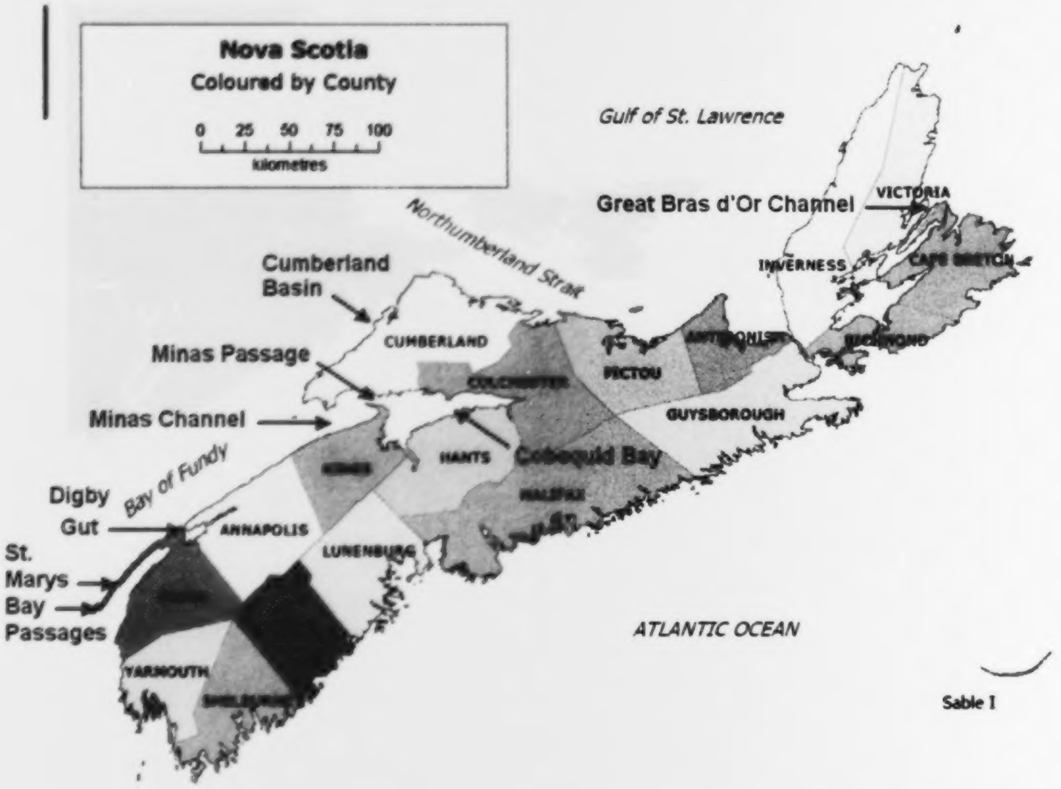

Nova Scotia
Coloured by County
0 25 50 75 100
kilometres
Gulf of St. Lawrence
Great Bras d'Or Channel
VICTORIA
Northumberland Strait
Cumberland Basin
INVERNESS
CAPE BRETON
CUMBERLAND
ANTIGONISH
RICHMOND
Minas Passage
COLCHESTER
PICTOU
GUYSBOROUGH
Minas Channel
HANTS
Cobequid Bay
Bay of Fundy
KINGS
HALIFAX
Digby Gut
ANNAPOLIS
LUNENBURG
St. Marys Bay Passages
ATLANTIC OCEAN
YARMOUTH
SHELBURNE
Sable I

Figure 1.2-1. Map showing eight potential TISEC project sites surveyed in this report.

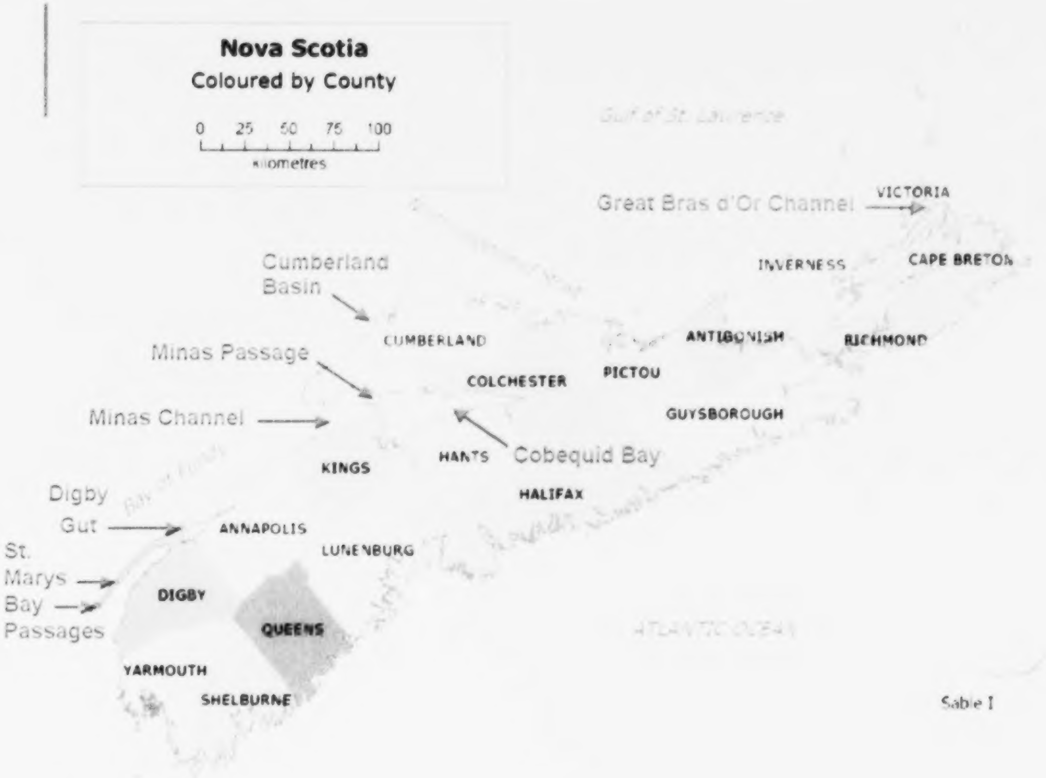
Section 4 of this report describes the site attributes that were used to characterize each of the above eight sites for Advisory Group evaluation of their potential suitability for a TISEC project.

Section 5 characterizes each of these sites according to these attributes, which include magnitude of tidal in-stream energy resource, seafloor geology, grid interconnection, nearby maritime infrastructure and harbor support services, potential conflicts with other uses such as navigation and commercial fishing, environmental issues, and possible unique opportunities associated with a particular site.

A list of references cited is provided as Section 6.

Appendix A presents a summary of the Nova Scotia power grid.

Appendix B describes the Nova Scotia shipyards and maritime industry.


Nova Scotia
Coloured by County
0 25 50 75 100
kilometres
Gulf of St. Lawrence
Great Bras d'Or Channel
VICTORIA
INVERNESS
CAPE BRETON
Cumberland Basin
CUMBERLAND
ANTIGONISH
RICHMOND
Minas Passage
COLCHESTER
PICTOU
Minas Channel
GUYSBOROUGH
KINGS
HANTS
Cobequid Bay
Digby Gut
HALIFAX
ANNAPOLIS
LUNENBURG
St. Marys Bay Passages
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4. Site Selection Criteria

The site selection criteria used in this assessment are:

1. Tidal current energy resource attributes (annual average energy flux per unit aperture area of TISEC device, and in-stream power density at ebb and flood peak flows)
2. Candidate site bathymetry and seafloor geology suitable for TISEC device foundation or anchoring system and submarine cable routing to shore (bottom composition, potential for sediment mobility under severe conditions, and bottom changes over time)
3. Coastal utility grid and substation loads and capacities, and availability of a suitable onshore grid interconnection point with a capability of handling the 500 kW pilot plant supply and with potential for growth to a 10 MW commercial plant.
4. Nearby regional shipyard labor and infrastructure for device fabrication and assembly, with sufficient local maritime infrastructure and harbor service vessels for system deployment, retrieval, and offshore servicing or in-harbor repair
5. Minimal conflict with competing uses of sea space (navigation channel clearance and maintenance dredging activities, commercial and sport fishing, protected marine areas) and likelihood of public acceptance
6. Unique opportunities to minimize project costs and/or attract supplemental funding, such as:
    - Existing utility easement which can be used to route power cable and shore crossing
    - High local demand and growth forecast, where installation of local generation source could eliminate need for distribution or transmission line upgrade
    - Plans for a roadway/railway bridge to cross a tidal channel yielding the opportunity to integrate and "buy down" the capital cost of civil works
    - Local public advocacy for project and highly-visible public education opportunity

4.1. Water Depth Requirements

Two example devices are considered, Marine Current Turbines' 1.2 MW twin-rotor device, which is supported by a monopile foundation, and Lunar Energy's 1.5 MW ducted turbine, which is installed on a gravity base.(note that both MCT and Lunar devices are scaleable in size)

Marine Current Turbines (MCT) employs a monopile foundation, as is commonly used for offshore wind energy projects in Europe. One of MCT's founding investors is Seacore, Ltd., a UK-based company specializing in non-oilfield marine drilling. Seacore has installed monopile foundations for at least five offshore wind energy projects, as well as MCT's Seaflow project.

A search of Seacore's project Web page at http://www.seacore.co.uk/categories.php?pID=86 indicated that their monopile technology has been applied mainly in firm seabeds of rock or hard clay. Any sediment overburden is "drilled through" and the monopile is grouted into a socket of 10 to 15 m penetration depth into the underlying bedrock (see Figure 4.1-1, below).

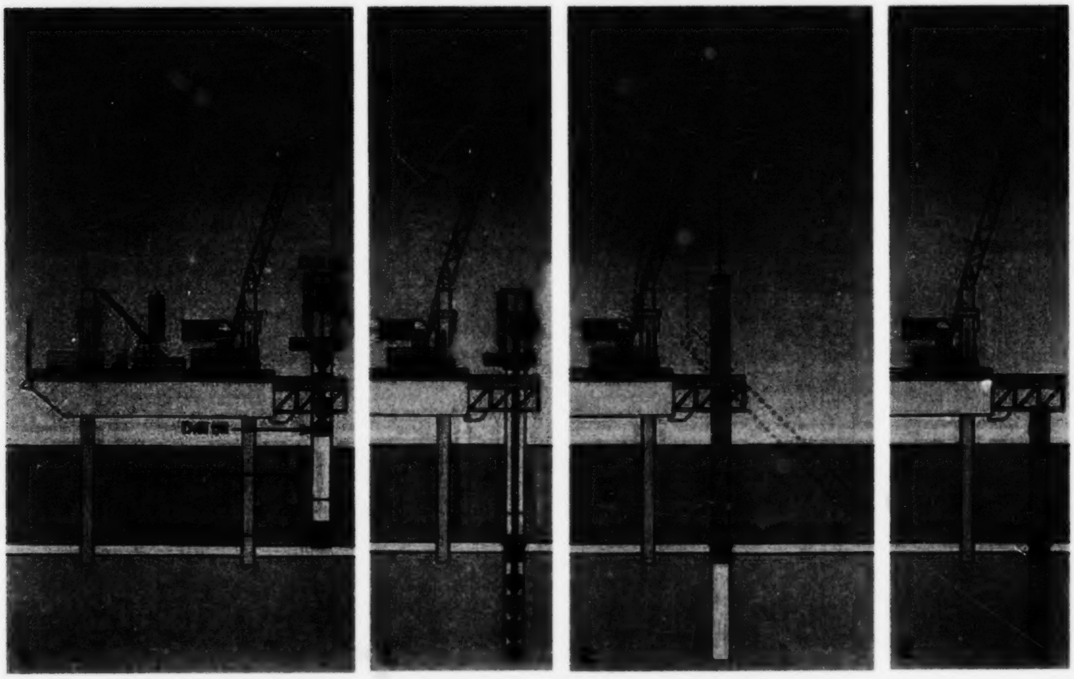

Figure 4.1-1. Monopile foundation installation sequence.

Seacore's jack-up barges can operate in water depths up to 30 m. Offshore wind energy cost models and feasibility studies indicate that monopile material and installation costs increase dramatically in water depths beyond 25 m. In deeper waters, MCT undoubtedly can apply the alternative fixed foundation concepts being investigated for offshore wind energy in 30-50 m water depths, such as the tripod, but these have not yet been proven in the ocean. Therefore, for purposes of the EPRI Phase I study, a monopile foundation concept is assumed.

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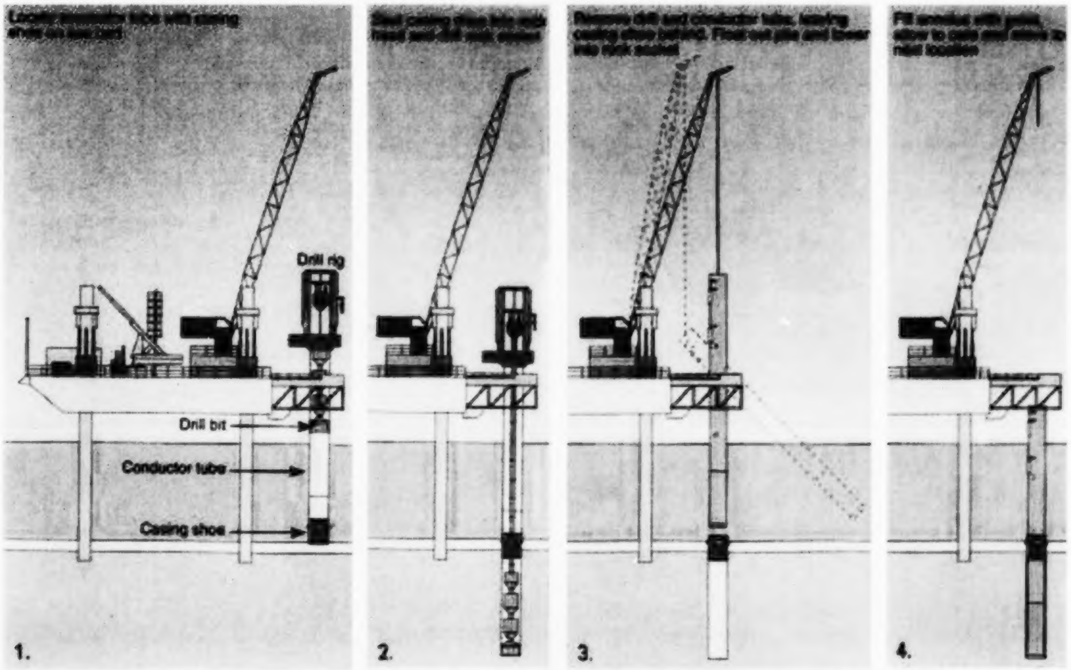

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For the 16-m rotor diameter of MCT's 1.2 MW Seagen device, a minimum water depth of 18 m would be required. MCT's Web site indicates that the required depth range for their commercial device is 20 to 30 m (http://www.marineturbines.com/background.htm), which is consistent with the above analysis.

By comparison, Lunar Energy's 1.5 MW ducted turbine has a minimum water depth requirement of 35 m (http://www.lunarenergy.co.uk/pdf/lunar_energy_brochure.pdf). This PDF brochure indicates the following specifications for their 1.5 MW unit to be as follows:

- Duct inlet diameter: 21 m
- Turbine diameter: 16 m
- Distance from seafloor to lower edge of duct: 8 m
- Minimum depth required: 35 m

These company specifications give an overhead clearance of 6 m, which is more than adequate to accommodate transiting commercial fishing vessels, ferries, most coastal research vessels, recreational motor vessels, and deep-keeled sailing vessels.

For channels and inlets used by oceangoing commercial shipping, including cruise ships and bulk carriers, which can have drafts of 10-15 m, a minimum clearance of 15 m would be required at extreme low water. Thus the depth required to accommodate the Lunar 1.5 MW turbine and oceangoing vessels passing overhead would be 44 m.

For Lunar's 2 MW unit, the following specifications are given in the EPRI 003 Device and Technology Survey Report:

- Duct inlet diameter: 25 m
- Turbine diameter: 19.5 m
- Total height above seafloor: 33 m)

These specifications imply that for the 2 MW Lunar turbine, a minimum depth of 38 m would be required in channels or inlets used by transiting commercial fishing vessels, ferries, most coastal research vessels, recreational motor vessels, and deep-keeled sailing vessels. In passages used by oceangoing commercial vessels, the minimum depth requirement would be 48 m.

4.2. Turbine Spacing and Project Area Requirements

According to Reference 6, environmental impact studies of the MCT device assume that turbines with diameters of 15.85-metres would be spaced out some 60-metres apart. This would leave a minimum gap of 44 metres from blade tip-to-tip. The turbines would be positioned 1000-metres downstream from each other in order to reduce the negatives effects on performance caused by turbulence (wake effects) and allow for the tidal streams to restore themselves. These spacings yield an installed capacity density of 21.6 megawatts (18 units x 1.2 MW) per km^2.

No information is available on the cross-channel spacing requirements for Lunar Energy's ducted turbines, but the units should be placed far enough apart on sediment bottoms to avoid excessive scouring due to flow acceleration between the ducts. Pending receipt of device-specific information, an upstream-downstream spacing of 1,000 m is assumed between rows.

5. Site Survey and Characterization

This section describes the attributes of each potential project site. Survey summary tables, listing key attributes in each category, are given first. Table 5-1 estimates the tidal in-stream energy resource in terms of intensity (power density) and magnitude (annual average extractable power and total potential installed capacity). Table 5-2 characterizes the seafloor geology, grid interconnection distances, and local maritime support infrastructure. Table 3-3 identifies potential conflicts with other uses, and unique opportunities.

Table 5-1. Summary of Site Tidal In-Stream Energy Resources

	Depth-Averaged Tidal In-Stream Mean Power Densities			**Channel Cross Section Flow Area (B)**	**Mean Extractable Power = 0.15A x B (C)**	**Total Potential Rated Project Capacity * = 0.8C / 0.4**
Site Name	During Peak Flood Flows Only	During Peak Ebb Flows Only	During Entire Year (A)			
Cumberland Basin	4.9 kW/m^2	4.9 kW/m^2	2.1 kW/m^2	20,600 m^2	6.5 MW	13 MW
Minas Channel	4.9 kW/m^2	4.9 kW/m^2	2.1 kW/m^2	415,000 m^2	131 MW	262 MW
Minas Passage	11.5 kW/m^2	11.5 kW/m^2	4.9 kW/m^2	226,000 m^2	166 MW	333 MW
Cobequid Bay	3.0 kW/m^2	3.0 kW/m^2	1.0 kW/m^2	42,200 m^2	6.3 MW	13 MW
Digby Gut	4.3 kW/m^2	4.3 kW/m^2	1.8 kW/m^2	18,000 m^2	4.9 MW	9.8 MW
Petit Passage	18 kW/m^2	7.7 kW/m^2	7.7 kW/m^2	8,000 m^2	9.2 MW	18 MW
Grand Passage	11.5 kW/m^2	11.5 kW/m^2	4.9 kW/m^2	9,000 m^2	6.6 MW	13 MW
Great Bras d'Or Channel	4.9 kW/m^2	4.9 kW/m^2	2.1 kW/m^2	4,500 m^2	1.4 MW	2.8 MW

* Note: This calculation assumes the project withdraws all of the Mean Annual Extractable Power given in the next-to-last column, converts it to electric power at an average power train efficiency of 80%, and that its average annual generated power is 40% of its total rated electrical capacity.

Table 5-2. Summary of Site Geological and Geographic Attributes

	Bathymetry and Geology		Grid Interconnection Distances and Costs*		First and Second Choices for Shoreside Maritime Support Center
Site Name	Channel Depth	Seafloor Properties	Commercial (10 MW) Plant	Demonstration (500 kW) Plant	
Cumberland Basin (1)	36 – 80 m	Gravel/mud, bedrock, rock/gravel	~20km to 69 kV	~6km to 24kV $300,000 to $400,000	Parrsboro NS somewhat preferred over Saint John NB
Minas Channel	46 – 70 m	Bedrock channel; gravel close to shore	>45km to 69 kV	>25km to 12kV >$1,500,000	Parrsboro NS somewhat preferred over Saint John NB
Minas Passage	36 – 110 m	Bedrock channel; gravel close to shore	~13km to 69 kV ~$1,560,000	~10km to 25kV ~$870,000	Parrsboro NS decidedly preferred over Saint John NB
Cobequid Bay	9 – 18 m	Bedrock channel; sand & mud close to shore	>30km to 69 kV	~6km to 12kV	Parrsboro NS decidedly preferred over Saint John NB
Digby Gut	9 – 61 m	Bedrock basalt	>10km to 69 kV	>7km to 12kV >$150,000	Saint John NB decidedly preferred over Yarmouth NS
Petit Passage	21 – 46 m	Bedrock basalt	>60km to 69 kV	~1km to 25kV	Saint John NB somewhat preferred over Yarmouth NS
Grand Passage (2)	9 – 21 m	Bedrock basalt	>75km to 69 kV	~1 km to 12kV	Saint John NB somewhat preferred over Yarmouth NS
Great Bras d'Or Channel	9 m	Bedrock sandstone, siltstone and shale	>10km to 138kV	~1 km to 25kV >$60,000	Sydney, NS

(1) Boss Point

(2) Cow Ledge

* Note: Interconnection distances and costs do not include submarine power cable to shore. Distances are approximate from shore crossing to grid interconnection point. Costs, where estimated, include any new line required, as well as upgrade of existing line.

Table 5-3. Summary of Site Societal Attributes

Site Name	Key Potential Conflicts	Unique Opportunities
Cumberland Basin	Minimal; few other uses.	Possible joint NB-NS project; possible UNESCO geological/fossil heritage site synergy (high visibility)
Minas Channel	Minimal; lobstering and scallop dragging precluded in deep and fast currents	Potential total installed capacity comparable to 11% of Nova Scotia Power's existing generation capacity
Minas Passage	Minimal; lobstering and scallop dragging precluded in deep and fast currents	Potential total installed capacity comparable to 14% of Nova Scotia Power's existing generation capacity
Cobequid Bay	Minimal; few other uses.	None identified.
Digby Gut	Busy channel with multiple users, including Saint John ferry, commercial fishing fleet, salmon farming, and lobstering	Excellent public visibility opportunity to demonstrate tidal in-stream devices relative to impoundment technology (as at nearby Annapolis Royal).
Petit Passage	Local ferry and recreational boat activity	Overhead power cable might be used for connection point
Grand Passage	Local ferry and recreational boat activity	Submerged cable corridor might provide useable easement
Great Bras d'Or Channel	Recreational boat activity	None identified

Detailed information supporting the above summary tables is given in the remainder of this section.

5.1 Cumberland Basin

The upper Bay of Fundy is split into two large bodies of water by Cape Chignecto, Nova Scotia. To the south is Minas Channel, which leads past Cape Split into Minas Basin. To the north is Chignecto Bay that is further divided by Cape Maringouin into Shepody Bay and Cumberland Basin (Figure 5.1-1). Cumberland Basin lies between New Brunswick (on its western shore) and Nova Scotia (on its eastern shore) and thus represents a potential site for a joint demonstration project by both provinces.

CUMBERLAND
BASIN

Figure 5.1-1. Geographic landmarks for Cumberland Basin (Reference 6).

5.1.1. *Tidal In-Stream Energy Resource*

The narrowest transect at the entrance to Cumberland Basin is shown in Figure 5.1-2, below. Also shown is the nearest location where measured current data exist, archived in the Ocean Data Inventory (ODI) maintained by the Department of Fisheries and Oceans Canada.

ODI Series Designation	Latitude (deg N)	Longitude (deg W)	Depth (m)	Series Start Date & End Date	Series Duration
MCM_65017_71_16_300	45.7566	64.45	5	18 Jun – 05 Jul 65	17 days

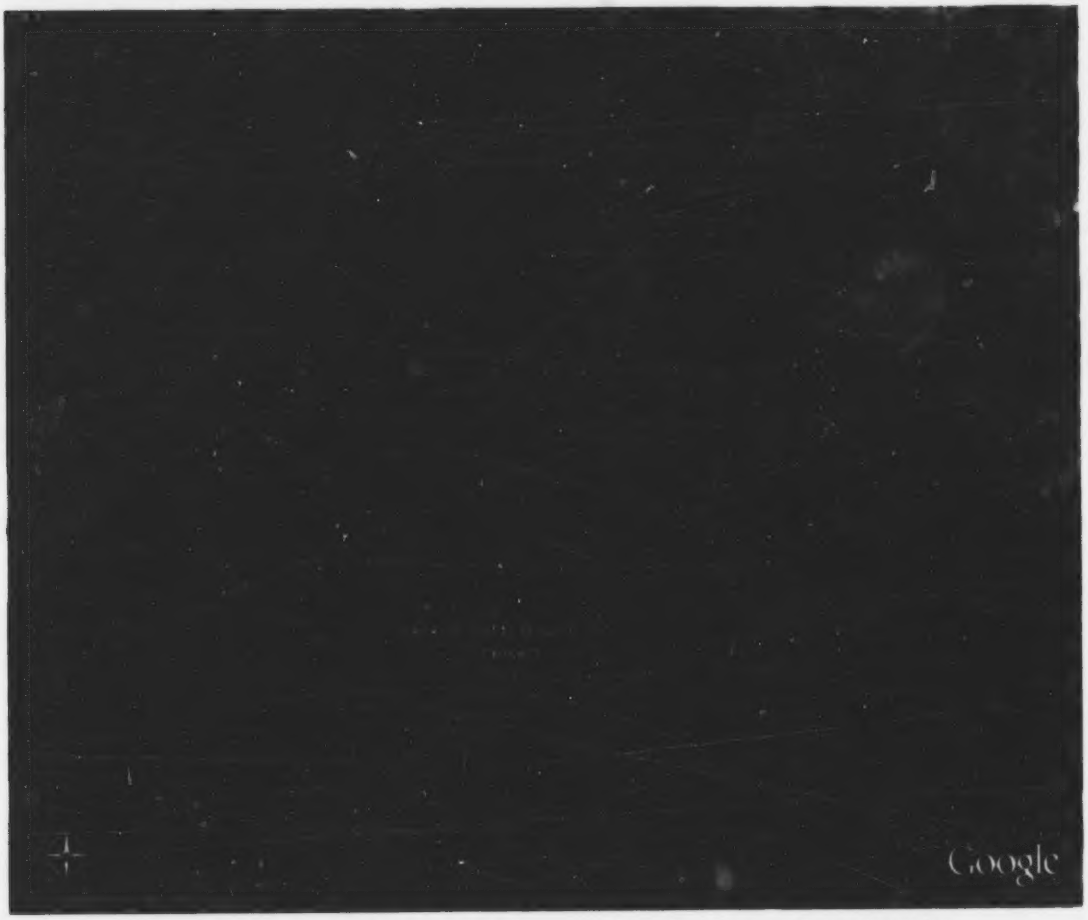

Figure 5.1-2. Aerial photograph from an altitude of approximately 30 km, showing the recommended transect in Cumberland Basin (Reference 6).

5.1 Cumberland Basin

The upper Bay of Fundy is split into two large bodies of water by Cape Chignecto, Nova Scotia. To the south is Minas Channel, which leads past Cape Split into Minas Basin. To the north is Chignecto Bay that is further divided by Cape Maringouin into Shepody Bay and Cumberland Basin (Figure 5.1-1). Cumberland Basin lies between New Brunswick (on its western shore) and Nova Scotia (on its eastern shore) and thus represents a potential site for a joint demonstration project by both provinces.

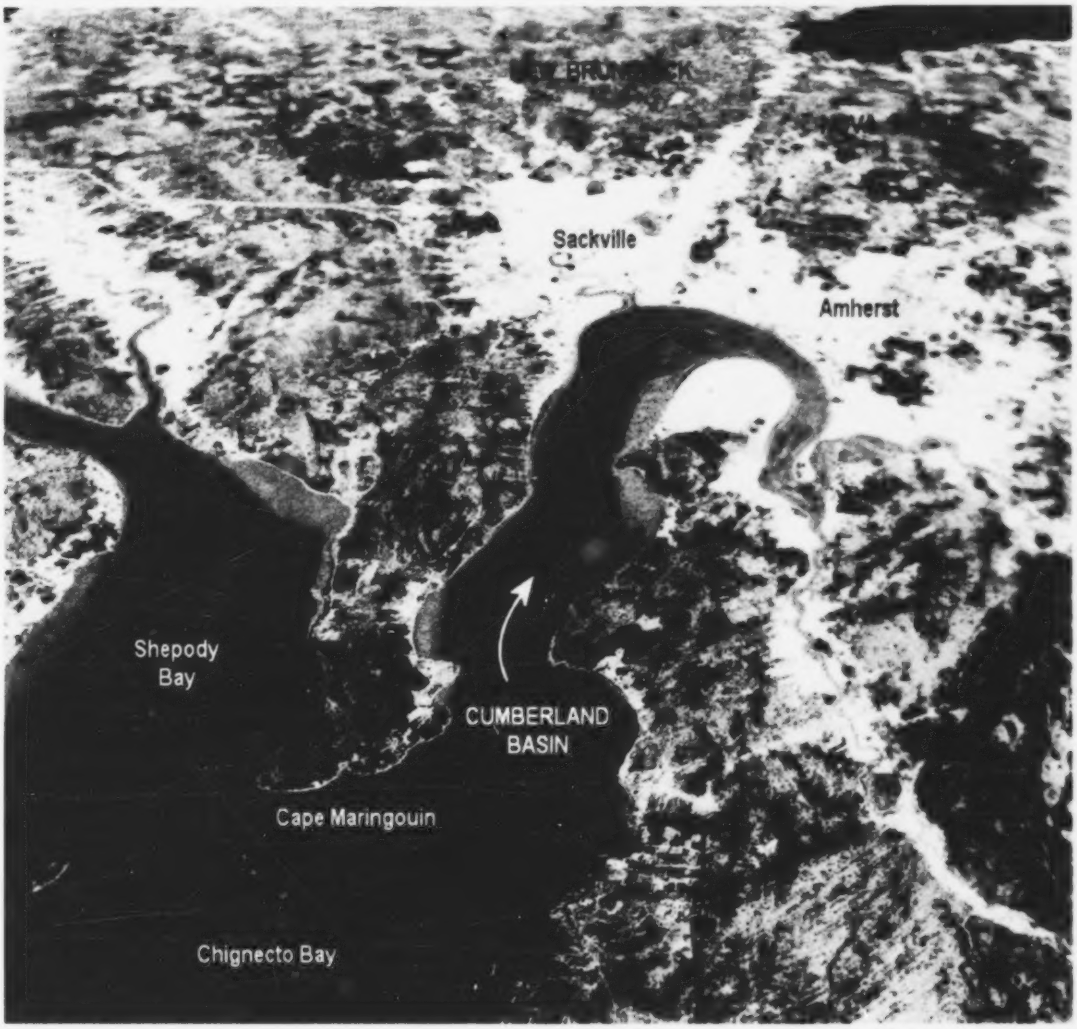
Sackville
Amherst
Shepody Bay
CUMBERLAND BASIN
Cape Maringouin
Chignecto Bay

Figure 5.1-1. Geographic landmarks for Cumberland Basin (Reference 6).

5.1.1. Tidal In-Stream Energy Resource

The narrowest transect at the entrance to Cumberland Basin is shown in Figure 5.1-2, below. Also shown is the nearest location where measured current data exist, archived in the Ocean Data Inventory (ODI) maintained by the Department of Fisheries and Oceans Canada.

ODI Series Designation	Latitude (deg N)	Longitude (deg W)	Depth (m)	Series Start Date & End Date	Series Duration
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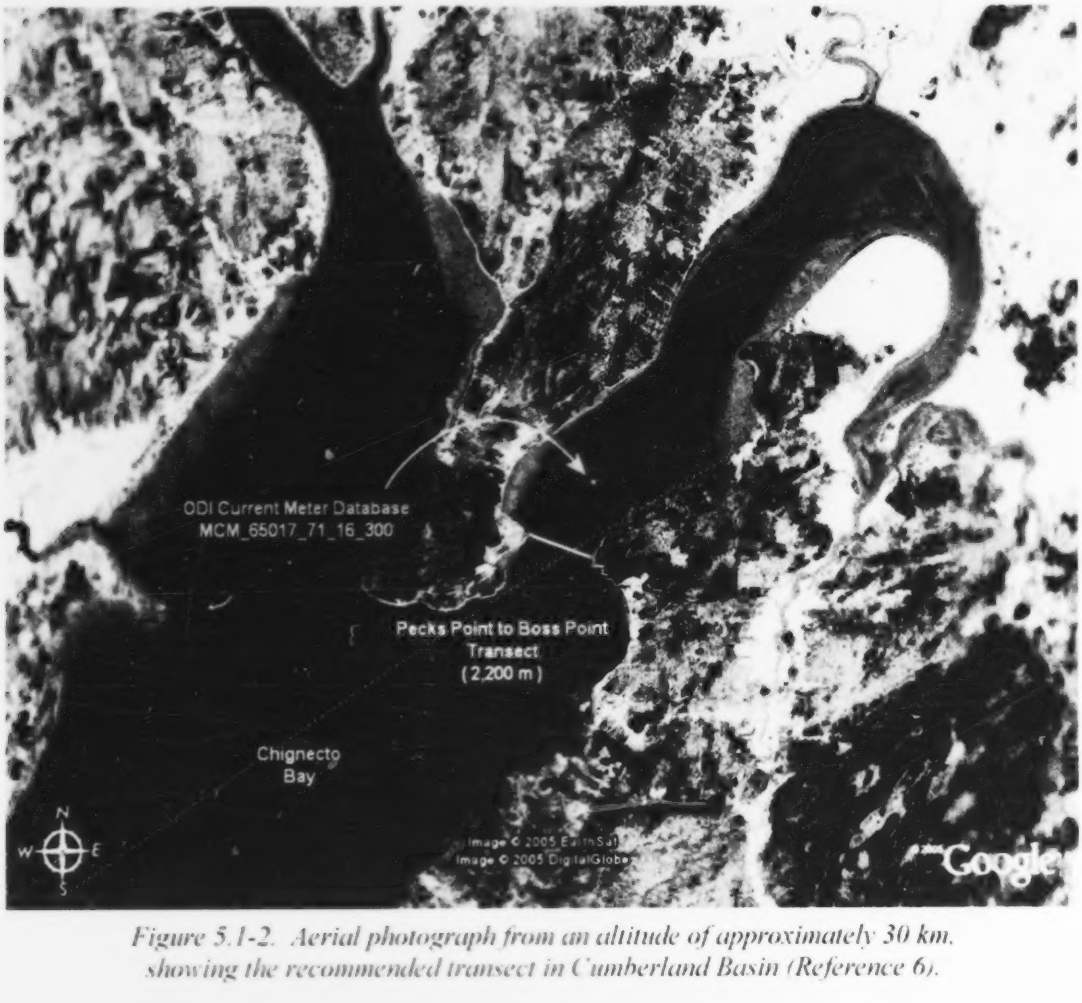

ODI Current Meter Database
MCM_65017_71_16_300
Pecks Point to Boss Point
Transect
(2,200 m)
Chignecto
Bay
N
W
E
S
Image © 2005 EarthSat
Image © 2005 DigitalGlobe
Google

Figure 5.1-2. Aerial photograph from an altitude of approximately 30 km, showing the recommended transect in Cumberland Basin (Reference 6).

Because the ODI current meter data archived for different sites in this report were not measured at the narrowest transects, they do not represent the best tidal stream resources. Also, because they were measured at different times at different sites, they cannot be directly compared for site selection purposes. Finally, there are some sites (Cobequid Bay, Digby Gut, and Grand Passage) for which there are no measured current data. Therefore, the average surface current speed of peak ebb and flood tidal currents noted on Canadian Hydrographic Service (CHS) charts were used as the basis for estimating the tidal stream resource at this and other potential sites.

CHS chart #4130 shows tidal current velocity vectors with the highest values of 4 to 5 knots in both ebb and flood directions at the narrowest tidal stream section off Boss Point (Figure 5.1-3). Tidal stream velocity vectors of a similar magnitude also occur further up Cumberland Basin off Wood Point. The calculation below uses the mid-point of this range, 2.3 m/s (4.5 knots), as the average peak surface current velocity, which corresponds to a peak tidal stream power density of 6.4 kW/m^2 at the surface.

Assuming that the time series profile of tidal stream velocity can be approximated by a sinusoidal curve, then the time-averaged velocity over one tidal period would be 63.7% of the peak velocity. Moreover, the mean value of the velocity-cubed over one tidal period would be 42.4% of the peak velocity cubed. Since tidal in-stream power density is proportional to velocity cubed, then the mean power density averaged over an entire tidal period would be 42.4% of 6.4 kW/m^2, which is 2.7 kW/m^2.

Since this is based on the surface velocity, it needs to be adjusted to estimate the depth-averaged tidal stream power density. Assuming that a 1/10-power law approximates the decrease in velocity from the surface to the bottom of the channel, then the depth-averaged value of velocity cubed would be 76.9% of its surface value. This yields a depth-averaged tidal stream power density of 4.9 kW/m^2 for peak ebb and flood currents, and 2.1 kW/m^2 averaged over time.

The cross-sectional area of the Cumberland Basin transect (see Figure 5.8-2) is reported by Reference 2 to be 20,600 m^2, giving a total resource base of 43,300 kW. Withdrawing 15% of this power yields an extractable resource of 6,500 kW. Assuming a "water to wire" conversion efficiency of 80% and a project capacity factor of 40%, then the maximum tidal in-stream capacity that could be installed at this site is 13,000 kW.

3.1.2 *Seafloor Bathymetry and Geology*

A hydrographic chart of the Cumberland Basin entrance is given below.

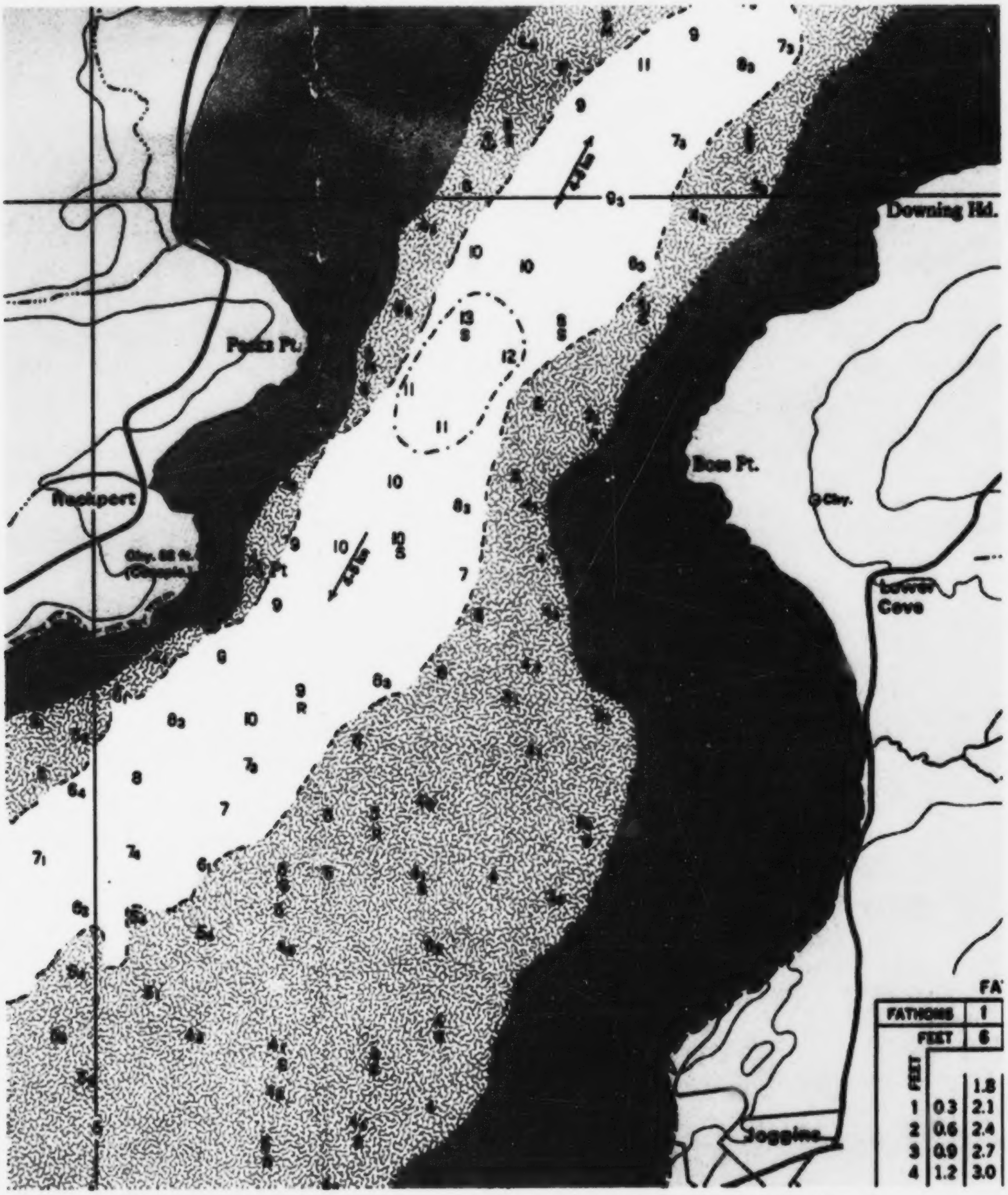

Downing Hd.
Pecks Pt.
Boss Pt.
Rockport
Lower Cove
Joggins
FATHOMS
FEET

Figure 5.1-3. Scanned section of CHS chart #4130 for Cumberland Basin. Depths are in fathoms, with additional feet as subscript (1 fathom = 6 ft = 1.8 m).

3.1.2 *Seafloor Bathymetry and Geology*

A hydrographic chart of the Cumberland Basin entrance is given below.

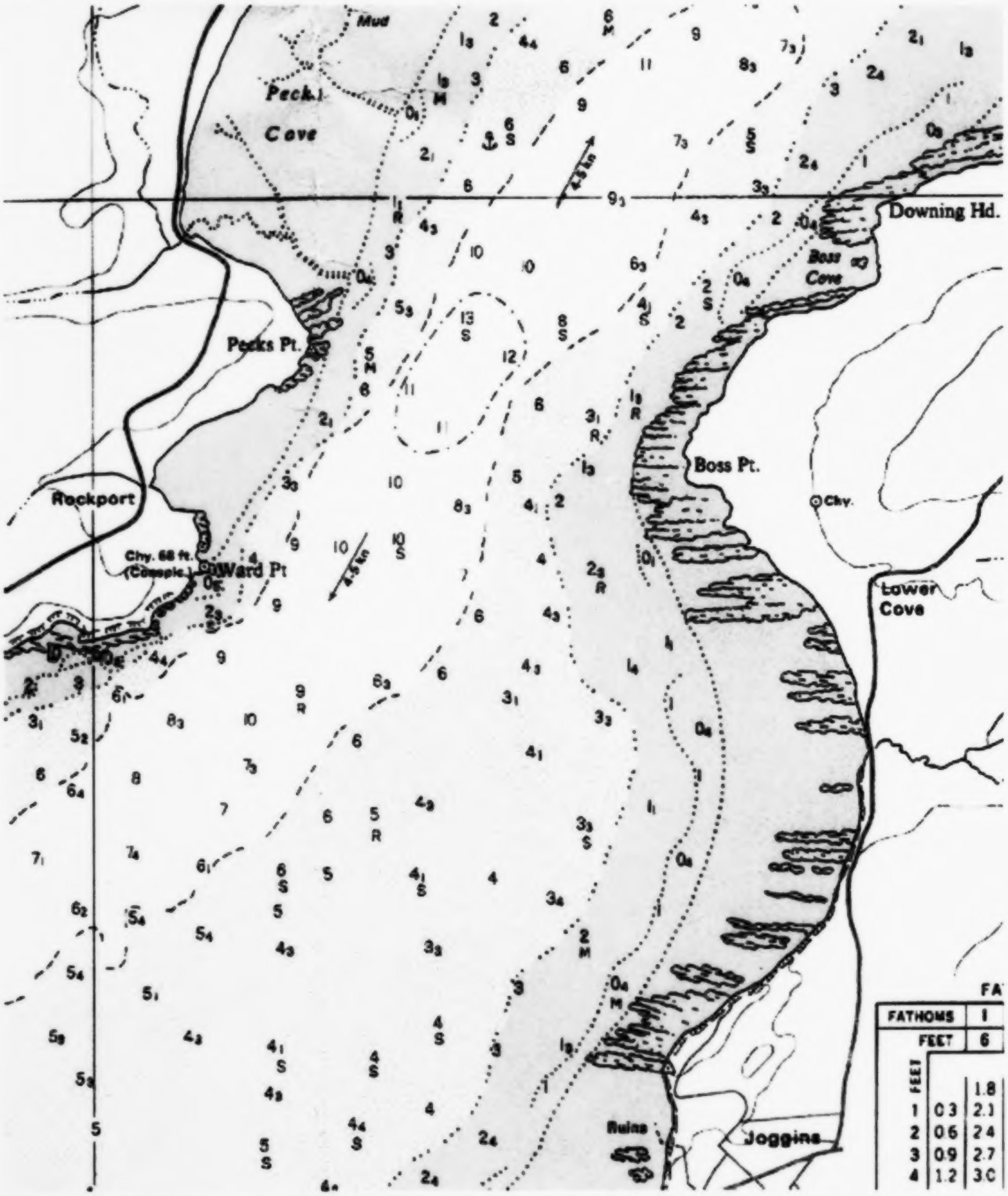

Mud
Peck Cove
Downing Hd.
Boss Cove
Pecks Pt.
Boss Pt.
Rockport
Chy.
Chy. 68 ft. (Conspic.)
Ward Pt
Lower Cove
Ruins
Joggins
FATHOMS
FEET

Figure 5.1-3. Scanned section of CHS chart #4130 for Cumberland Basin. Depths are in fathoms, with additional feet as subscript (1 fathom = 6 ft = 1.8 m).

Cumberland Basin has been studied as part of early tidal power barrage assessments in the 1960s and 70s and geological surveys have been conducted to investigate oceanographic conditions, sediment transport, adjacent cliff recession and seabed surficial geology. As many as four tidal barrage sites were explored in Cumberland Basin, and the final chosen one was between Ward Point and Joggins Point, termed the A8 crossing (Reference 7).

The Pecks Point to Boss Point transect of Cumberland Basin is the narrowest section. Sediments are thick (up to 60 m) on the central to western side of the transect, interpreted as a glacial river valley that has been in-filled (Figure 3.1-5). The bedrock beneath the sediments is Carboniferous sandstone, conglomerate and limestone. Sand bedforms and scour depressions may occur on the seabed but their presence needs to be investigated, if this site is ever to be further considered.

During the earlier tidal power investigations, considerable geo-scientific information was developed for the channel section south of Boss Point, between Joggins Head and Ward Point. Geological conditions appear to be the same for the region between Pecks Point and Boss Point to the north.

Figure 5.1-5 is an interpretation of the land bedrock geology and a cross-section extending from Ward Point to Joggins Head. The control for collected vibrocores, nearshore drill holes and diamond drill holes is also shown, as are the strike and dip of the bedrock beds.

The cross-section of Figure 5.1-5 is taken from the Atlantic Tidal Programming Board Report of 1969 (Reference 7). The cross-section shows the bedrock surface to be at the seabed on the eastern side and that the thickest sediments occur in the centre of the channel and are approximately 60 feet thick. Roughness of the seabed in the centre may result from the presence of sand bedforms or current scour features cut into the sediments. This is not clear from the cross-section. Sidescan sonograms or multibeam bathymetry need to be collected for verification. The cross-section also shows three surficial units overlying bedrock as well as the structure within the bedrock beneath the seabed.

Figure 5.1-6 shows two additional cross-sections 61 m to the north and south of the Ward Point to Joggins head crossing. They show similar bedrock distributions and morphology as well as the thickness of surficial sediments suggesting that conditions are uniform in the entrance to Cumberland Basin over a broad area.

Note that many of the tidal barrage caissons were designed to be placed directly on the surficial sediments and not on bedrock following removal of the sediment overburden. The authors of Reference 7 evidently considered the strength of these surficial sediments adequate to support such caisson structures. Additional surveys should be conducted to determine if the thick layer of valley-fill sediments in the western side of the Cumberland Basin entrance has sufficient strength to support a monopile foundation or a turbine gravity base.

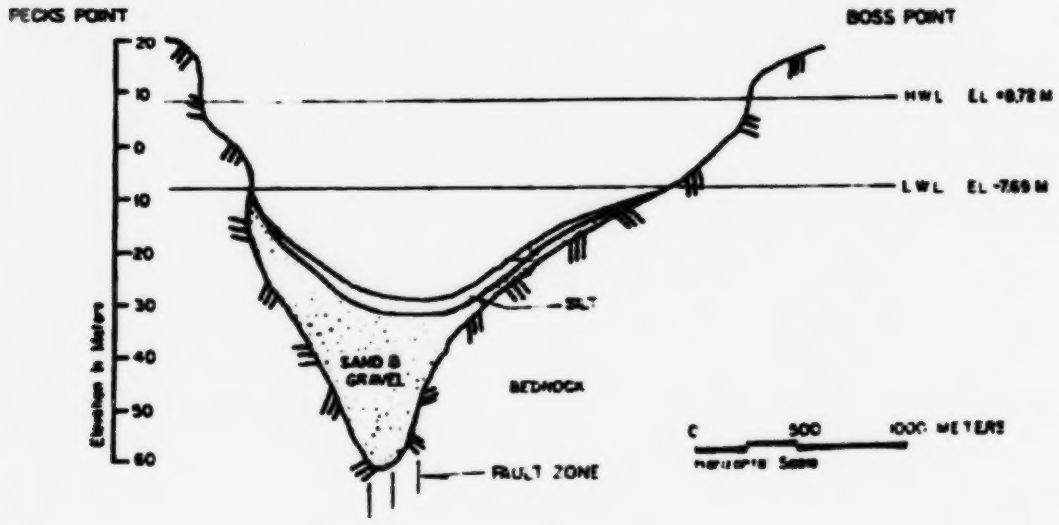

PECKS POINT
BOSS POINT
20
10
0
-10
-20
-30
-40
-50
-60
Elevation in Meters
HWL EL +8.72 M
LWL EL -7.69 M
SILT
SAND & GRAVEL
BEDROCK
FAULT ZONE
0 500 1000 METERS
Horizontal Scale

Figure 5.1-4. Sediment thickness in Cumberland Basin transect between Pecks Point, New Brunswick and Boss Point, Nova Scotia. The sediment overburden is 10 m or less in the eastern half of the transect, and up to 40 m thick in the buried river valley of the western half.

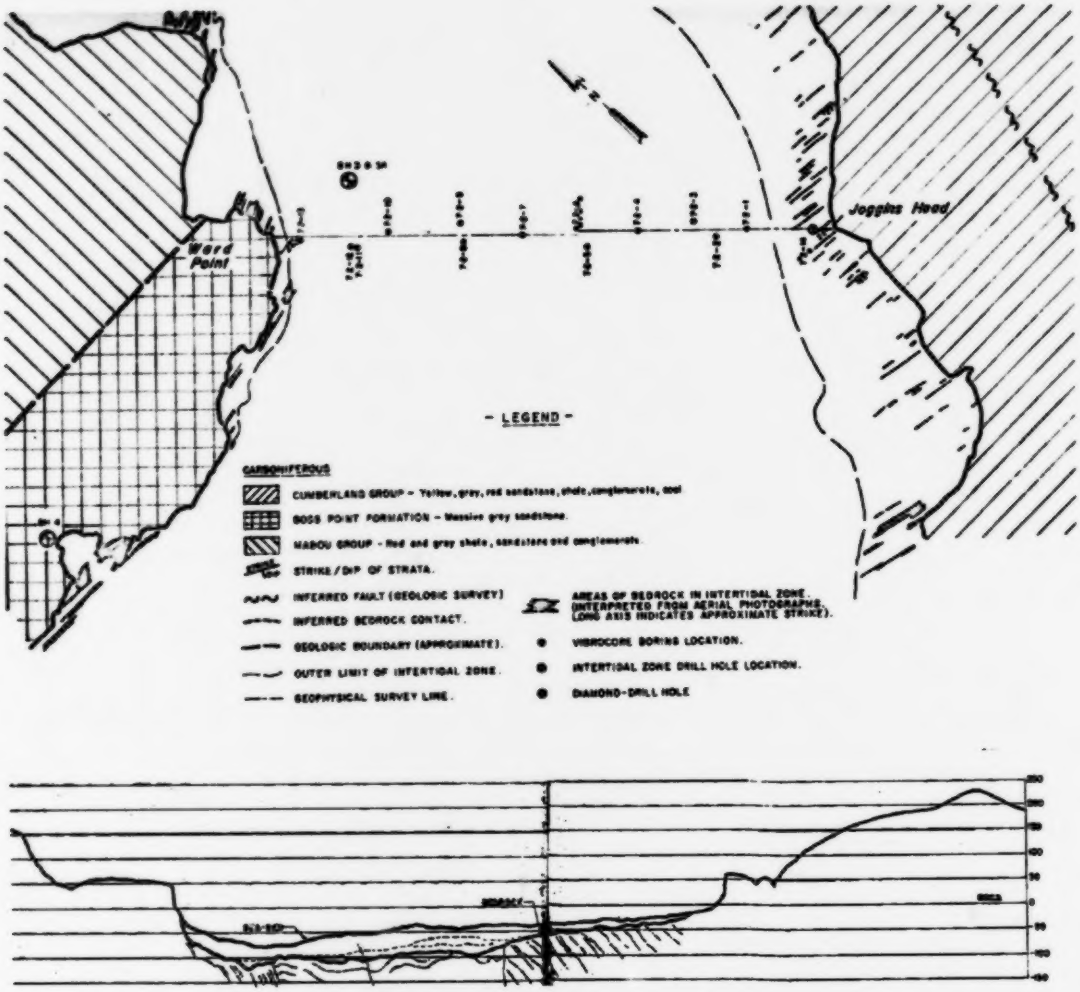
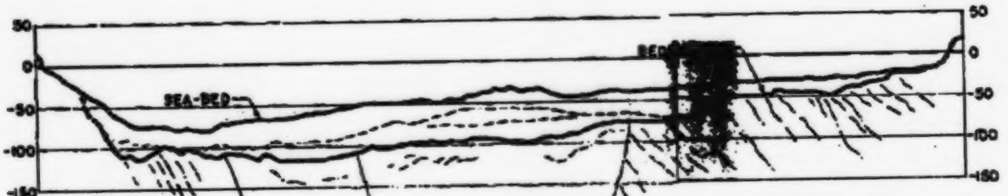
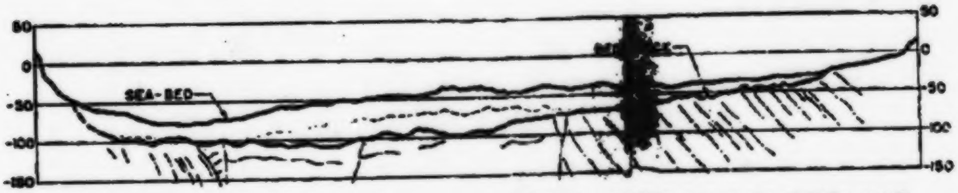

Ward Point
Joggins Head
- LEGEND -
CARBONIFEROUS
CUMBERLAND GROUP – Yellow, grey, red sandstone, shale, conglomerate, coal
BOSS POINT FORMATION – Massive grey sandstone.
MABOU GROUP – Red and grey shale, sandstone and conglomerate.
STRIKE / DIP OF STRATA.
INFERRED FAULT (GEOLOGIC SURVEY)
INFERRED BEDROCK CONTACT.
GEOLOGIC BOUNDARY (APPROXIMATE).
OUTER LIMIT OF INTERTIDAL ZONE.
GEOPHYSICAL SURVEY LINE.
AREAS OF BEDROCK IN INTERTIDAL ZONE. (INTERPRETED FROM AERIAL PHOTOGRAPHS. LONG AXIS INDICATES APPROXIMATE STRIKE).
VIBROCORE BORING LOCATION.
INTERTIDAL ZONE DRILL HOLE LOCATION.
DIAMOND-DRILL HOLE
CENTRELINE GEOPHYSICAL PROFILE

Figure 5.1-5. Geophysical survey and geological interpretation of channel cross-section at Cumberland Basin entrance between Ward Point and Joggins Wharf.


50
0
-50
-100
-150
SEA-BED
BED
50
0
-50
-100
-150

GEOPHYSICAL PROFILE 200' NORTHEAST OF CENTRELINE


50
0
-50
-100
-150
SEA-BED
50
0
-50
-100
-150

GEOPHYSICAL PROFILE 200' SOUTHWEST OF CENTRELINE

Figure 5.1-6. Additional channel cross-sections at Cumberland Basin entrance, suggesting uniformity of seafloor geology over a broad area.

5.1.3 Utility Grid Interconnection

Interconnection to the NSPI grid is shown in Figure 5.1-7 for 25 kV and Figure 5.1-8 for 69 kV.

Boss Point 45° 44' 5.98" N lat, 64° 26' 53.24" W long.
To waters edge requires 5+ km of new line plus 1km to border (NB)
Rough cost estimate: $300,000 to 400,000
Maximum size for induction generator: 2 MW
Maximum size for direct-drive generator: 3 MW

Figure 5.1-7 Onshore interconnection point for Cumberland Basin

Joggins – line 26N substation – (fed by circuit 30N412 to 30N interconnection to 69 kV at Maccan, 19.5 Km away)

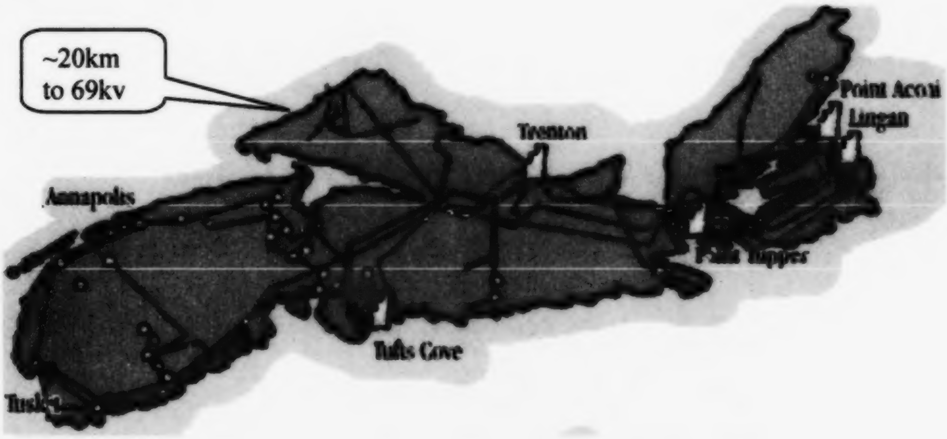

~20km
to 69kv
Point Aconi
Lingan
Trenton
Annapolis
Point Tupper
Tufts Cove
Tusket

Figure 5.1-8 Distance from Site to Closest 69kV Connection

5.1.4. Maritime Support Infrastructure

Appendix B provides information about marine support services and fabricators in Nova Scotia. As detailed there, a wide variety of shipyards and offshore marine contractors exists is the Halifax-Dartmouth area, well suited for fabrication and assembly of TISEC devices.

For shoreside support services (inspection, maintenance, and repair of operating devices), the nearest city with an extensive maritime infrastructure is Saint John, New Brunswick, but this port is located approximately 130 km southwest of Cumberland Basin. A service vessel traveling at a cruising speed of 12-14 knots (24 KPH) would require a transit time of 4-1/2 hours if going with the current, or 5-1/2 hours if going against the current. At a tow speed of 6-7 knots (12 KPH), the trip would take 9 to 11 hours, depending on timing relative to the tide.

Parrsboro, Nova Scotia, has a well-maintained wharf and is located just inside the Minas Passage, with a water route distance of only 85 km from Cumberland Basin. A service vessel traveling to Boss Point at a cruising speed of 12-14 knots (24 KPH) would require a transit time of 2-1/2 hours if going with the current, or 4-1/2 hours if going against the current. At a tow speed of 6-7 knots (12 KPH), the trip would take 5 to 9 hours, depending on timing relative to the tide.

Compared to coming from Saint John, a vessel's response time from Parrsboro would be 1 to 2 hours faster for investigating a problem or delivering a service crew to the project site, and would be 2 to 4 hours faster if towing a device. This saves fuel and reduces down time for a device outage incident. It also minimizes exposure to waiting-on-weather delays, compared to a trip that covers half the length of the Bay of Fundy. Moreover, compared to Saint John, the local weather at Parrsboro is more like the weather in Cumberland Basin, reducing the risk of unexpected wave or wind conditions found by the service vessel when it arrives on site.

Parrsboro Harbor (45°23'N., 64°19'W) is approached between Partridge Island to the west, and Clarke Head to the east. Lighthouse Bar, which is covered at extreme high water, and a breakwater extend about 800 meters to the northeast from Crane Point, which is itself 1.3 km northeast of Partridge Island. Parrsboro Light is shown from the breakwater on the western side of the harbor entrance.

The tidal range at Parrsboro is 11.3 to 12.5 m during neap tides, and 12.7 to 14.2 m during spring tides. There is a least depth of approximately 6.7m at neap high water in the middle of the entrance opposite the light on the breakwater.

Parrsboro has a well-maintained public wharf, with a berthing length of 100 m and a hardwood vessel bed 100 m long and 16 m wide that dries alongside (Figure 5.1-9). Off Parrsboro Lighthouse, there is good anchorage in depths of 11 m outside the harbor entrance.

The Parrsboro Harbour Commission has been briefed on this study and is keen to provide local support for tidal in-stream projects in the upper Bay of Fundy. Moreover, they have significant funding from the Atlantic Canada Opportunity Agency (ACOA) to improve their harbor facilities, as well as a work building with a gantry crane support structure next to the short leg of the public wharf (Figure 5.1-10). There is no working crane on the gantry structure, and the building is currently used only for storage. With proper planning and consultation, it is possible that a graving dock could be dredged right up to the waterfront end of this building.

Figure 5.1-9 Parrsboro Harbour public wharf at high and low tides, looking north.

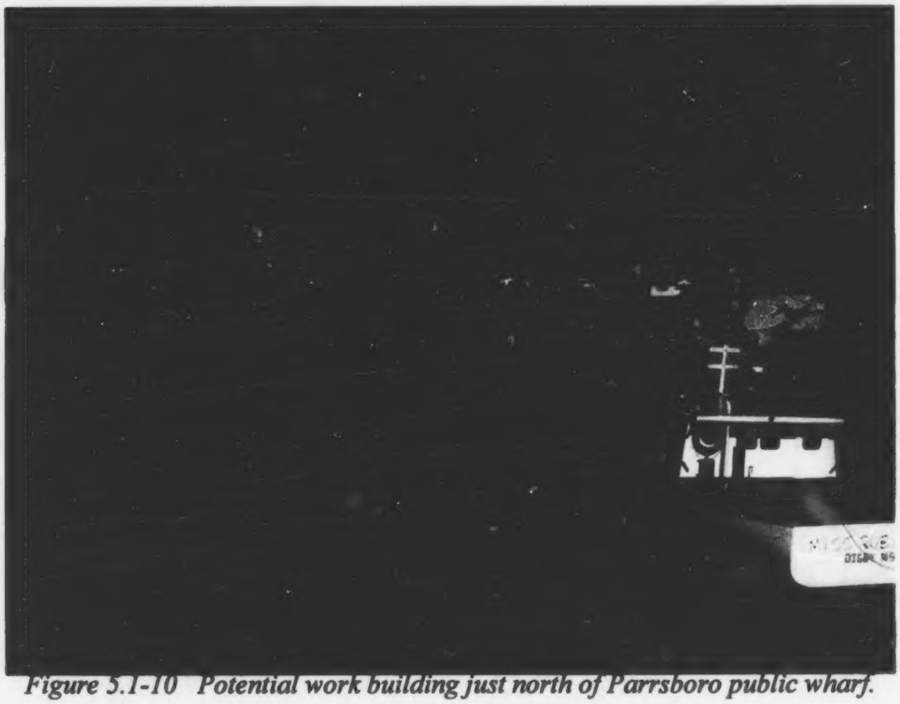


Figure 5.1-10 Potential work building just north of Parrsboro public wharf.

Another possible shoreside support center is Hantsport (45°04'N, 64°10'W), which is located on the west bank of the Avon River, about 5 km upstream from its entrance at Horton Bluff on the southwest shore of Minas Basin. Hantsport is a tidal port, capable of serving vessels with a draft of up to 9.8 m, although vessels are usually restricted to a maximum draft of 7.6 m.

The pier and wharf described below are served by a rail line that enters town from the south, but there is a steep grade down from the rail line to the waterfront, with only a narrow road leading to the public wharf. Unlike Parrsboro, there is no vacant land or developable property adjacent to these waterfront facilities, which are largely dedicated to the maritime operations of two private companies. It is difficult to see how a TISEC service facility could be established here.

The public wharf is 137 m long, with a vessel bed equally long and 18 m wide, which dries 4.9 m alongside. Minas Basin Pulp and Power Company operates a large plant and warehouses served by this wharf (Figure 5.1-11).

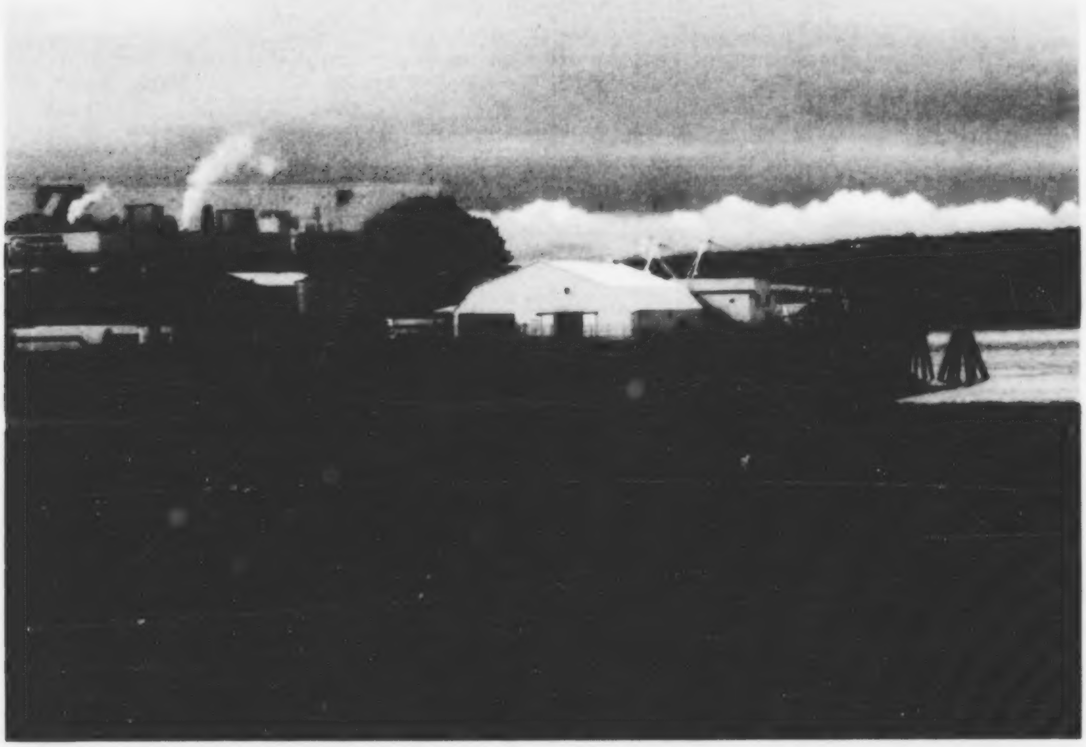


Figure 5.1-11 Hantsport waterfront facilities, looking north. Fundy Gypsum Company pier is visible at right, behind public wharf. Note vessel bed alongside public wharf at water's edge. Minas Basin Pulp and Power Company buildings dominate left side of picture.

Just north of the public wharf is the Fundy Gypsum Company pier, which is 152 m long and dries 4 m alongside (Figure 5.1-12). There is no vessel bed here; ore carriers dock three hours before high water and depart at high water on the same tide. This pier is equipped with conveyors capable of loading about 20,000 tons of ore onto a vessel in three hours. The company-owned tug that helps maneuver the gypsum carriers is berthed along the north side of the public wharf to the south (Figure 5.1-13).

Figure 5.1-12 Fundy Gypsum Company conveyer and pier.

Figure 5.1-12 Fundy Gypsum Company tug moored on north side of public wharf.

5.1.5. Environmental Considerations

Migratory shorebirds have been observed in the Cumberland Basin at Minudie, but in much smaller numbers than occur in the well-known shorebird preserves in Shepody Bay or the Southern Bight of Minas Basin. Furthermore, Minudie is well north of the Pecks Point – Boss Point transect, so the potential for disturbing significant numbers of shorebirds is remote.

The cliffs at Joggins, south of Boss Point, have recently been recognized as a UNESCO world heritage site encompassing a 10 km stretch of sea cliffs up to 30 m high. Preserved in the cliff face is a succession of Pennsylvanian age fossil swamp forests, including standing tree trunks up to 6 m high, a vast array of invertebrates, fish, amphibians and early reptiles, forerunners of the dinosaurs. The study of plant and animal fossils from these cliffs have been so instrumental in the development of geological and evolutionary principles, that these fossil beds are often referred to as a "Coal Age Galapagos."

Apart from being careful that cable shore crossings avoid these fossil beds, this site seems to have few environmental concerns.

5.1.6 Unique Opportunities

The development of an in stream tidal generation facility would compliment the tourist and development plans of the region, especially if presented as a modern energy alternative to the coal in the cliffs, as a truly sustainable non-polluting development.

A new fossil interpretive center has been designed, and the manager for its construction is keen to employ green energy technologies for the building.

5.2 Minas Channel

To the south of Cape Chignecto is Minas Channel leading to Minas Basin through Minas Passage. The Channel has a slight curvilinear path to the northeast and then southeast as it migrates around Cape Split and becomes Minas Passage (Figure 5.2-1).

MINAS
CHANNEL

Figure 5.2-1. Geographic landmarks for Minas Channel (Reference 6).

5.2.1. Tidal In-Stream Tidal In-Stream Energy Resource

Potential project transects in Minas Channel are shown in Figure 5.2-2, below. Also shown is the nearest location where measured current data exist, archived in the Ocean Data Inventory (ODI) maintained by the Department of Fisheries and Oceans Canada.

ODI Series Designation	Latitude (deg N)	Longitude (deg W)	Depth (m)	Series Start Date & End Date	Series Duration
MCM_65017_75_27_300	45.3633	64.6166	10	08 Aug – 23 Aug 65	15 days

Figure 5.2-2. Aerial photograph from an altitude of approximately 30 km, showing the numerically modeled transects in Minas Channel (Reference 6).

5.2 Minas Channel

To the south of Cape Chignecto is Minas Channel leading to Minas Basin through Minas Passage. The Channel has a slight curvilinear path to the northeast and then southeast as it migrates around Cape Split and becomes Minas Passage (Figure 5.2-1).

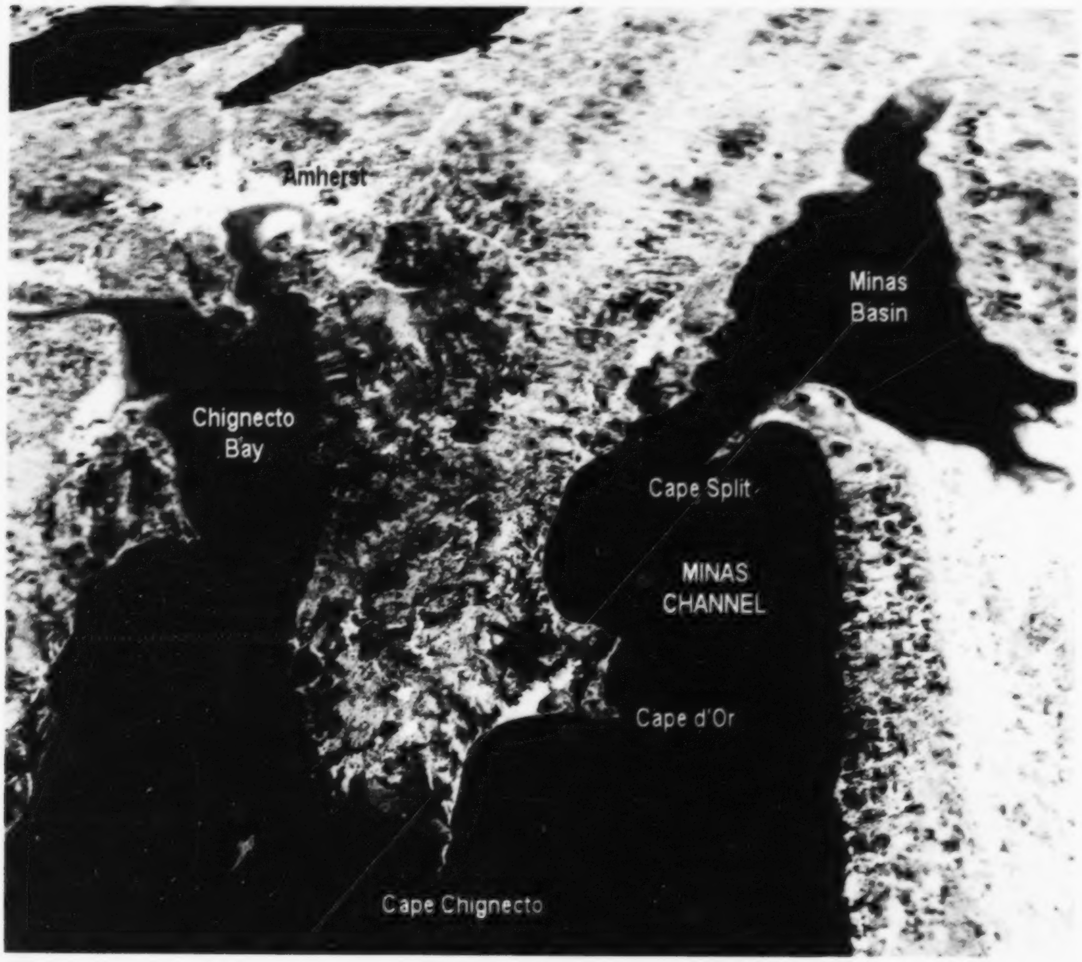

Amherst
Minas Basin
Chignecto Bay
Cape Split
MINAS CHANNEL
Cape d'Or
Cape Chignecto

Figure 5.2-1. Geographic landmarks for Minas Channel (Reference 6).

5.2.1. *Tidal In-Stream Tidal In-Stream Energy Resource*

Potential project transects in Minas Channel are shown in Figure 5.2-2. below. Also shown is the nearest location where measured current data exist, archived in the Ocean Data Inventory (ODI) maintained by the Department of Fisheries and Oceans Canada.

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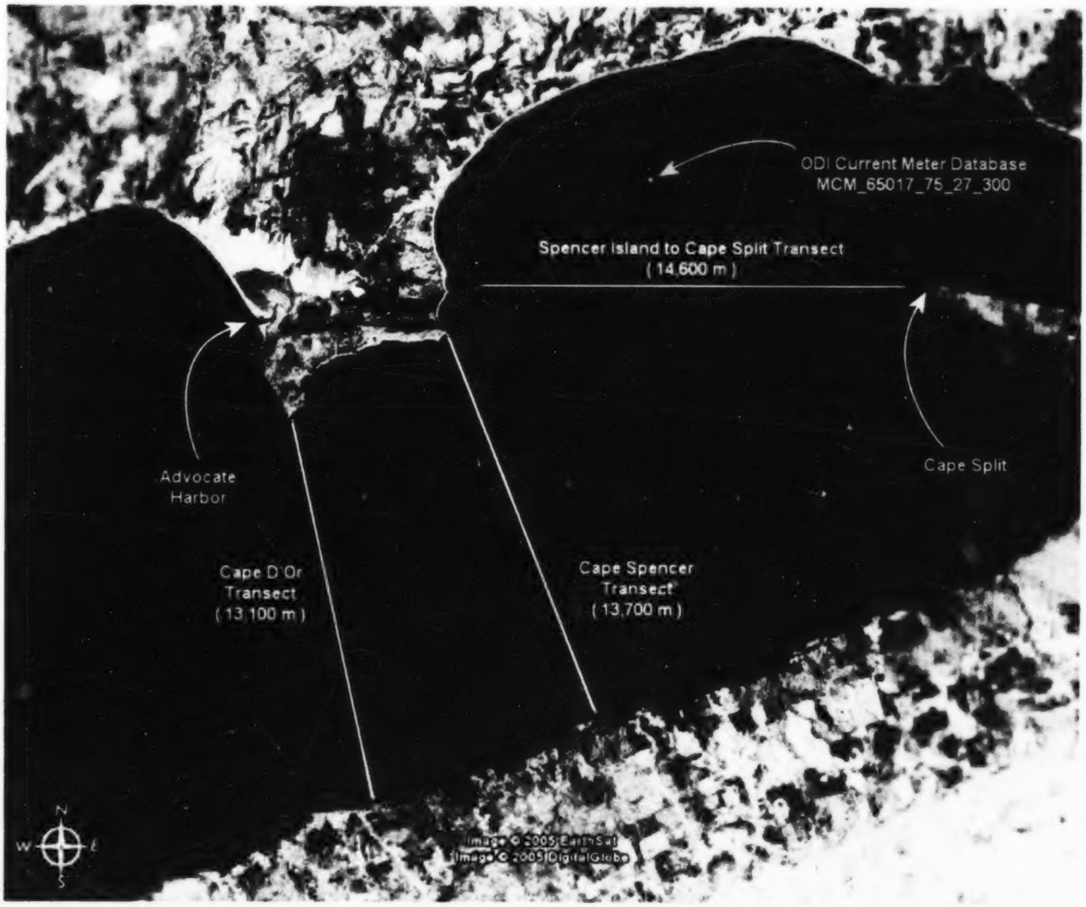

ODI Current Meter Database
MCM_65017_75_27_300
Spencer Island to Cape Split Transect
(14,600 m)
Advocate Harbor
Cape Split
Cape D'Or Transect
(13,100 m)
Cape Spencer Transect
(13,700 m)
N
W
E
S
Image © 2005 EarthSat
Image © 2005 DigitalGlobe

Figure 5.2-2. Aerial photograph from an altitude of approximately 30 km, showing the numerically modeled transects in Minas Channel (Reference 6).

CHS chart #4010 shows a number of current velocity vectors with the highest values of 6 knots in both ebb and flood directions immediately off Cape Spencer (Figure 5.2-3). Current velocities of 5 knots in either direction are shown further offshore, toward the middle of the channel. Tidal current speeds are significantly less, only 3 knots, in Greville Bay, against the northeast shore of Minas Channel, and likewise only 3 knots against the south shore off Black Rock (southern end of Cape d'Or transect) and Huntington Point (southern end of Cape Spencer transect). The calculation below uses 4.5 knots as the channel-wide average peak current velocity, which corresponds to a peak tidal stream power density of 6.4 kW/m^2 at the surface.

Assuming that the time series profile of tidal stream velocity can be approximated by a sinusoidal curve, then the time-averaged velocity over one tidal period would be 63.7% of the peak velocity. Moreover, the mean value of the velocity-cubed over one tidal period would be 42.4% of the peak velocity cubed. Since tidal in-stream power density is proportional to velocity cubed, then the mean power density averaged over an entire tidal period would be 42.4% of 6.4 kW/m^2, which is 2.7 kW/m^2.

Since this is based on the surface velocity, it needs to be adjusted to estimate the depth-averaged tidal stream power density. Assuming that a 1/10-power law approximates the decrease in velocity from the surface to the bottom of the channel, then the depth-averaged value of velocity cubed would be 76.9% of its surface value. This yields a depth-averaged tidal stream power density of 4.9 kW/m^2 for peak ebb and flood currents, and 2.1 kW/m^2 averaged over time.

The cross-sectional area of the Minas Channel off Cape d'Or and Cape Spencer was estimated from the bathymetric contour chart in Figure 3.2-5 to be 415,000 m^2, giving a total resource base of 871,500 kW. Withdrawing 15% of this power yields an extractable resource of 130,700 kW. Assuming a "water to wire" conversion efficiency of 80% and a project capacity factor of 40%, then the maximum tidal in-stream capacity that could be installed at this site is 261,500 kW.

5.2.2. *Seafloor Bathymetry and Geology*

A hydrographic chart of the Minas Channel is given below.

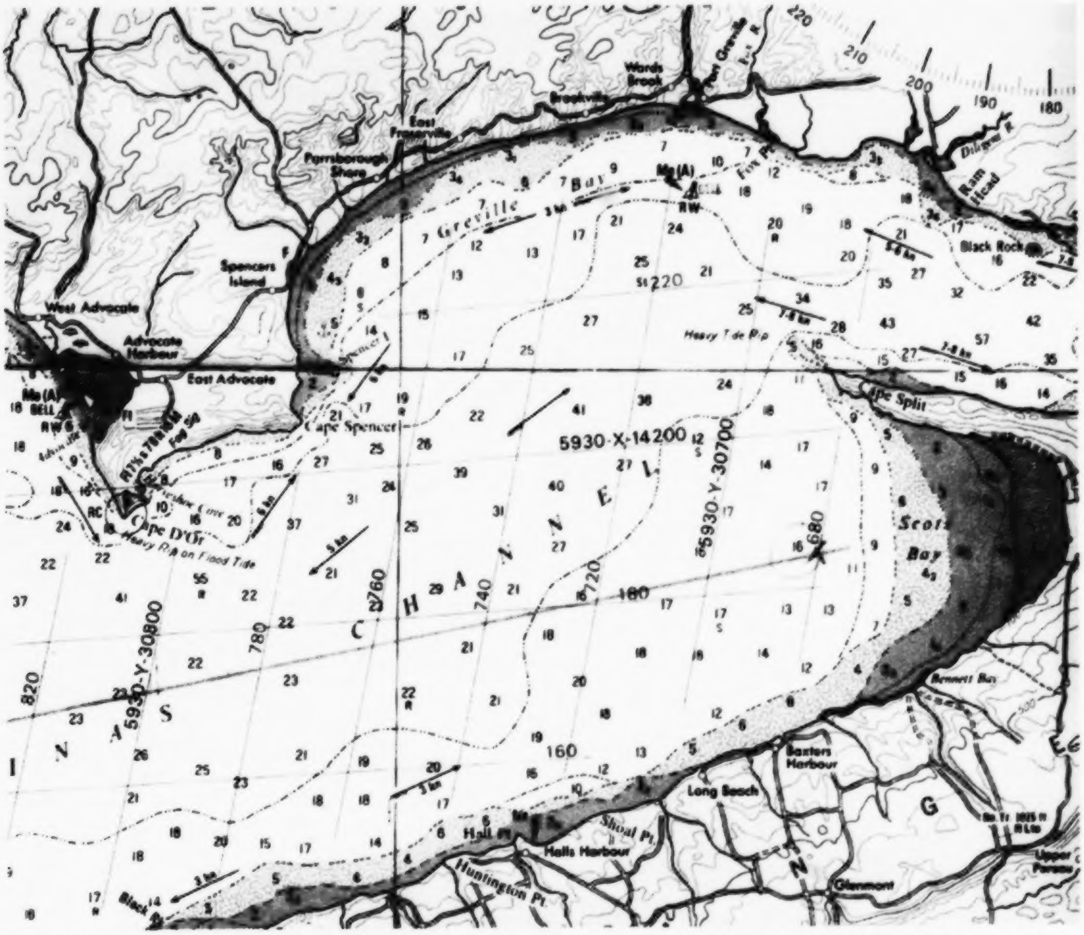

Wards Brook
Brookville
East Fraserville
Parrsborough Shore
Spencers Island
West Advocate
Advocate Harbour
East Advocate
Cape Spencer
Cape D'Or
Greville Bay
Heavy Tide Rip
Cape Split
Black Rock
Ram Head
Scots Bay
Bennett Bay
Baxters Harbour
Long Beach
Shoal Pt
Halls Harbour
Hall Pt
Huntington Pt
Glenmont
Upper Canard
Black Rock
MINAS CHANNEL
5930-X-14200
5930-Y-30700
5930-Y-30800
220
210
200
190
180
160
680
720
740
760
780
820

Figure 5.2-3. Scanned section of CHS chart #4010 for Minas Channel. Depths are in fathoms, with additional feet as subscript (1 fathom = 6 ft = 1.8 m).

As with the Cumberland Basin, Minas Channel has been studied as part of early tidal power proposals in the 1960s and 70s and geological surveys have been conducted to investigate seafloor conditions and sediment distribution. As many as three tidal power barrage sites were explored in Minas Channel and the final chosen one was between Cape Spencer and the south coast near Huntington Point, termed the B3 crossing (Reference 7).

The deepest areas of Minas Channel are in the northern part and have had multibeam bathymetry collected. In the deep depressions of up to 70 m water depth, the seabed is ridged and is interpreted to represent exposed bedrock. Also on the basis of grab samples alone, the deep channel has been mapped as a bedrock bottom.

The bedrock geology of most of the floor of Minas Channel is Triassic sedimentary bedrock. The synclinal axis of the Triassic basin occurs in the middle of the channel off Cape D'Or and veers toward the centre of the hook of Cape Split. North Mountain Formation basalt occurs along the south shore of the channel and at the Cape D'Or and Cape Spencer areas of the north shore. Another outlier of volcanic rocks occurs off Cape Split to the west.

On both sides of the deep depressions, the seabed is mapped as gravel. The gravel is likely a lag deposit formed over thick glaciomarine sediments in the subsurface. Scouring of these sediments produces fresh-looking scarps which suggest that processes of deepening and eroding the seabed are active. The actual area of bedrock outcrop *vs.* scoured sediment scarps needs to reconciled between the multi-beam interpretation and the interpreted distribution from grab samples alone, as the two differ.

The sediment distribution based on samples alone is mapped in Figure 5.2-4, which shows that much of Minas Channel consists of gravel with a central linear area of bedrock outcrop. A bathymetric contour chart to the same scale is shown in Figure 5.2-5, which shows three deep depressions on the north side of the channel. The most westerly depression occurs due south of Cape D'Or and is over 70 m in depth. A slightly shallower depression occurs to the east with a depth of 60 m. Still further to the east is another larger depression bounded by the 70 m contour.

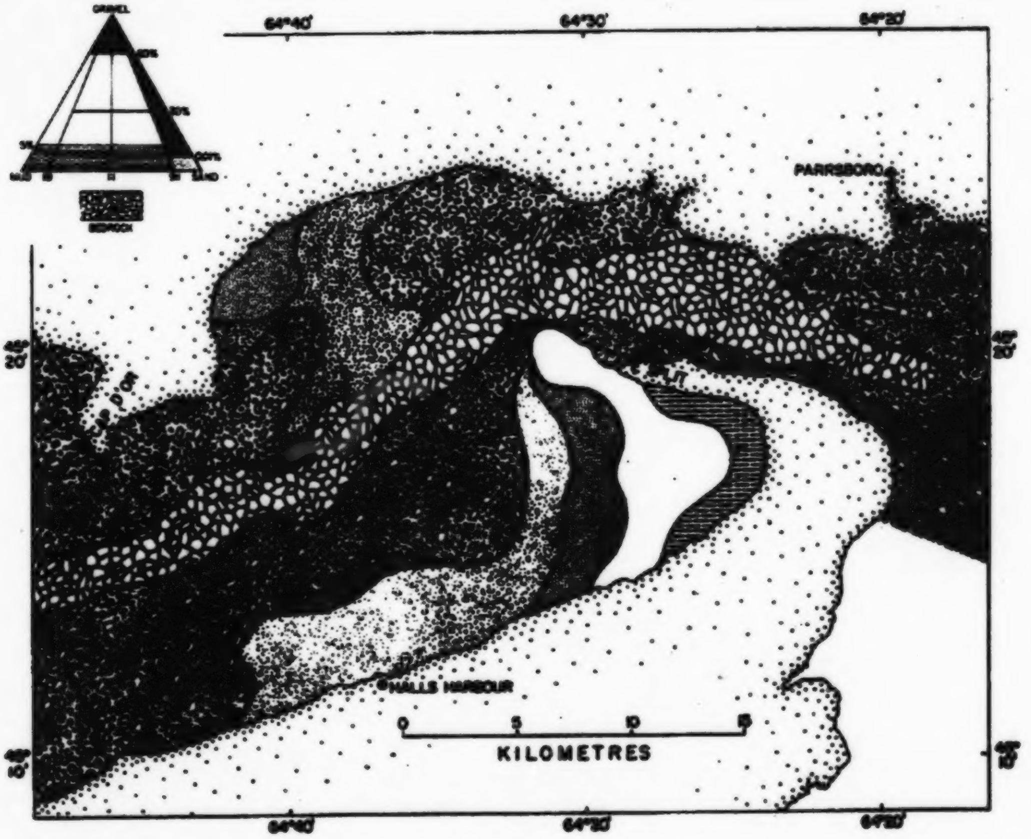
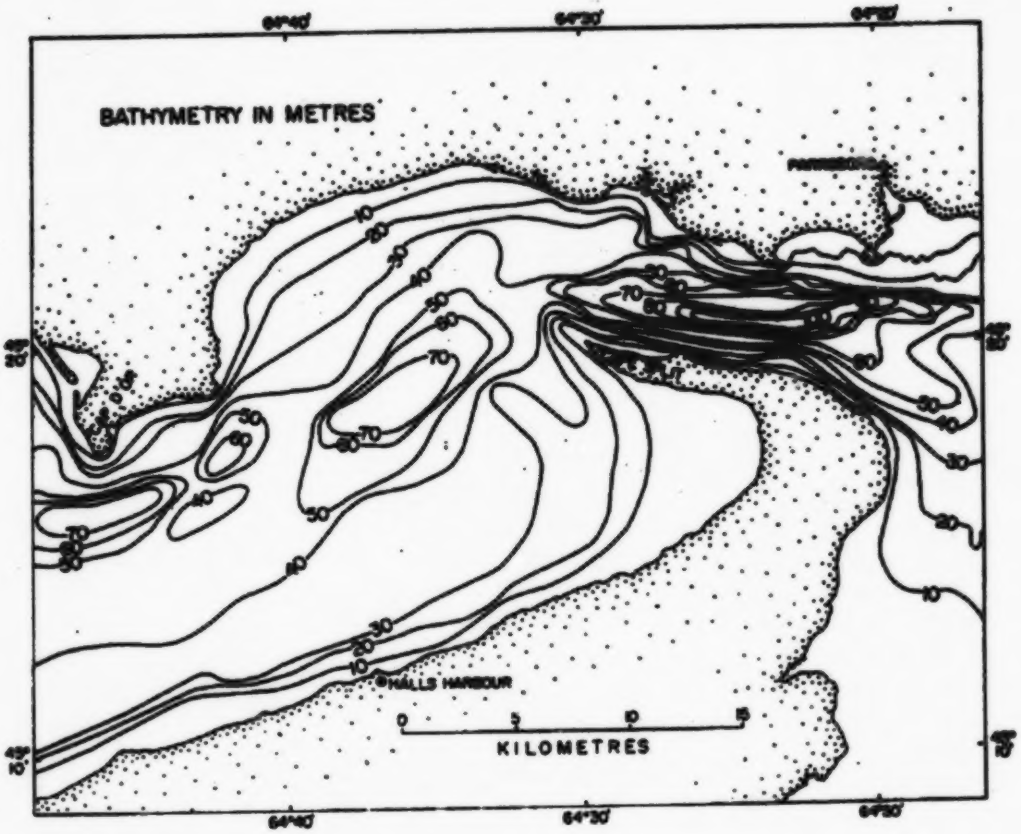

GRAVEL
MUD
SAND
BEDROCK
64°40'
64°30'
64°20'
45°20'
45°10'
PARRSBORO
HALLS HARBOUR
0
5
10
15
KILOMETRES

Figure 5.2-4. Sediment and bedrock distribution in Minas Channel and Minas Passage.


BATHYMETRY IN METRES
64°40'
64°30'
64°20'
45°20'
45°10'
10
20
30
40
50
60
70
HALLS HARBOUR
0
5
10
15
KILOMETRES

[illegible]

There are two areas within Minas Channel that have been surveyed with multibeam bathymetry and were chosen for study because they had the deepest depths and previously mapped bedforms. These are a long linear area on the north side of the channel centered off Cape D'Or and an area east of Cape Split.

The area south of Cape D'Or and Cape Spencer covers the two deep depressions in the west of the channel and the western part of the third depression. The following is an interpretation of the multibeam image shown in Figure 5.2-6, based on sample control and limited seismic reflection information.

The dominant characteristic of the area is a deep linear trough cut into subsurface glaciomarine stratified sediments. Exposed at the base of the trough are linear ridges that likely represent sandstone bedrock. The western area of the depression has a steep eroded flank with fresh looking scour features suggesting that erosion is presently occurring and that the depression is elongating to the west.

To the southeast of Cape D'Or in shallower water is a large body of sand with large sand dunes in a teardrop-shaped feature. Local scour of the seabed occurs in other places. There is a prominent ridge at the seabed between the most easterly and the adjacent depression. It trends north-south and may represent a large sand bedform or a volcanic intrusive bedrock feature. A wide variety of materials and environments occur in this region and most are indicative of extreme currents with erosion and deposition. A thorough integration of the multibeam bathymetry with the geophysical survey data is required for a better understanding of the materials and processes in this dynamic setting.

The second multibeam bathymetric imagery lies to the west of Cape Split over a sand body called the Cape Split Sand Dune Field. This imagery shows a classic lensoid-shaped deposit of sand in a field of large sand waves, which commonly occur throughout the Bay of Fundy adjacent to headlands. These features develop in response of local eddies and sediment deposition. The eastern side of this sand deposit shows transport to the north and the western side shows transport to the south with a shear zone in the middle. Repetitive surveys to this area show that the bedforms change substantially in terms of height, spacing and distribution, but the primary sand body does not appear to move. To the north of the sand wave field, the multibeam data shows the deep channel area as a series of ridges interpreted to be outcropping bedrock.

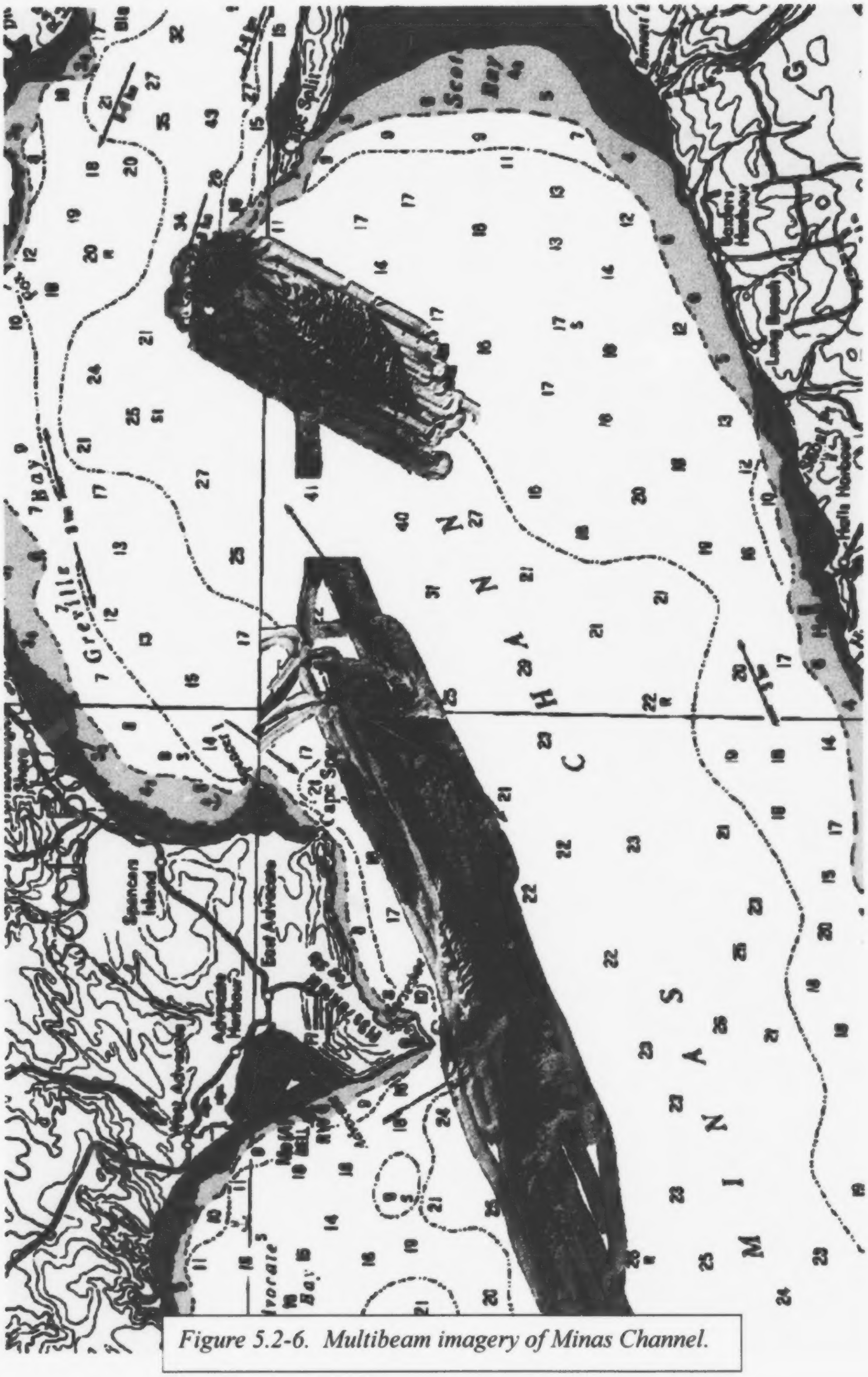

Scots Bay
Greville Bay
Cape Split
Spencers Island
East Advocate
Advocate Harbour
West Advocate
Baxters Harbour
Halls Harbour
MINAS CHANNEL

Figure 5.2-6. Multibeam imagery of Minas Channel.

5.2.3. Utility Grid Interconnection

Interconnection to the NSPI grid is shown in Figure 5.2-7 for 12 kV and Figure 5.2-8 for 69 kV.

East Advocate – weak line 12KV
25+km of new/ upgrade work from 37N-412
Maximum size for induction generator: 1 MW
Maximum size for direct-drive generator: 2 MW
Estimated cost: $1,500,000

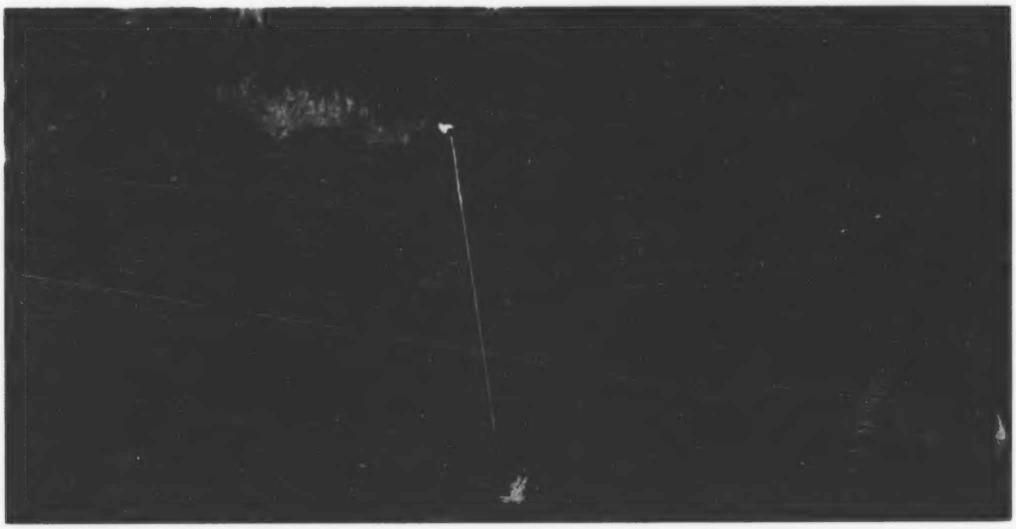


Figure 5.2-7 Distance from Site to Closest 12 kV Distribution Line for Nominal 500 kW Plant (8km, less if site is closer to shore)

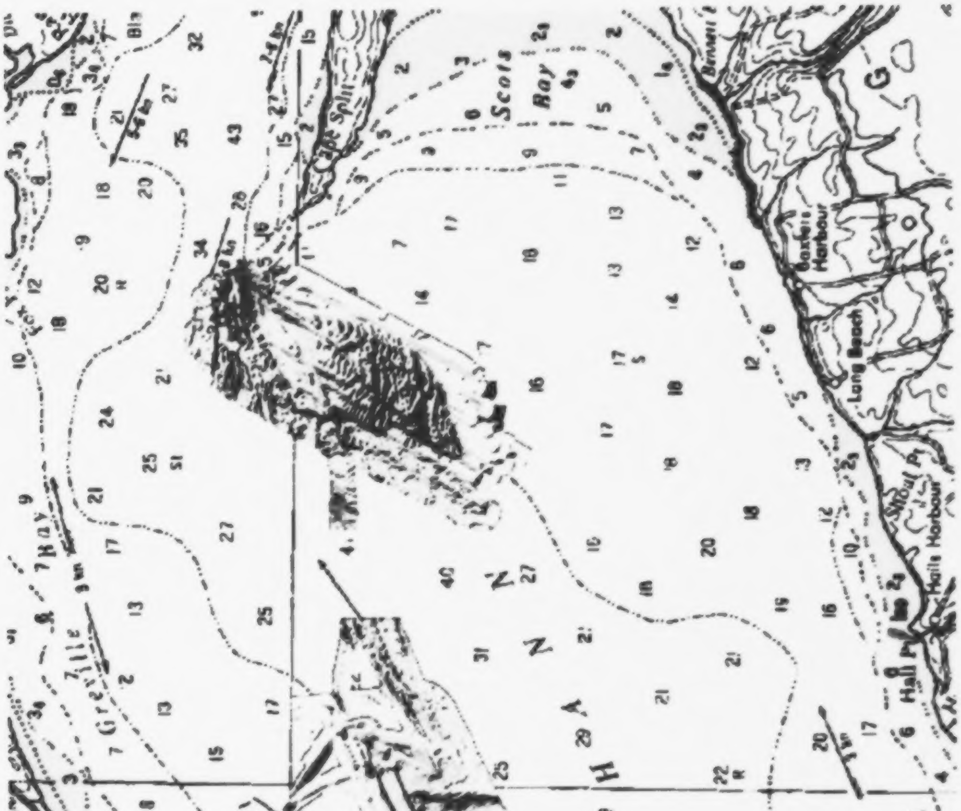

Scots Bay
Baxters Harbour
Long Beach
Haile Harbour
Hall Pt
Greville Bay
Spencers Island
East Advocate
Advocate Harbour
West Advocate
Cape Split
MINAS CHANNEL

Figure 5.2-6. Multibeam imagery of Minas Channel.

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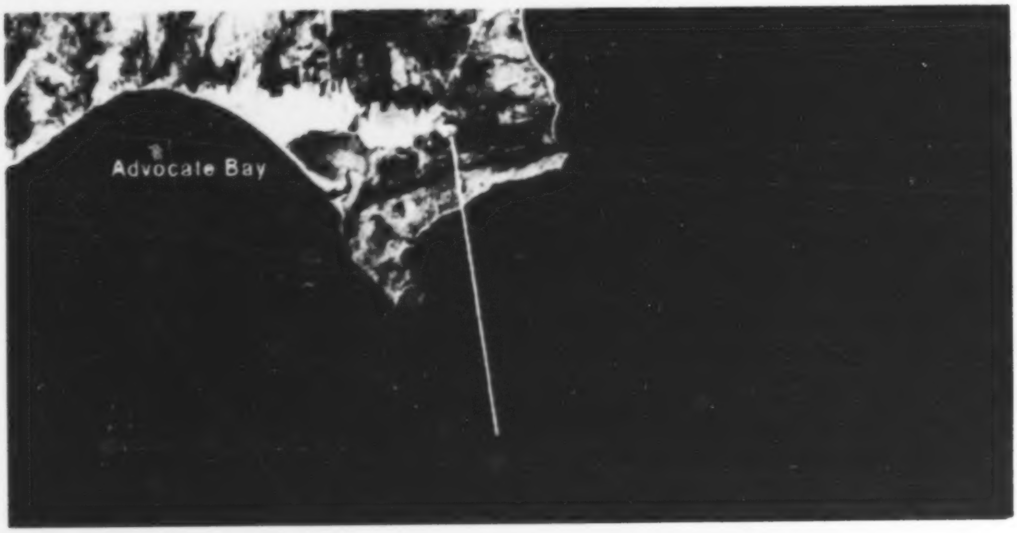

Figure 5.2-7 Distance from Site to Closest 12 kV Distribution Line for Nominal 500 kW Plant (8km, less if site is closer to shore)

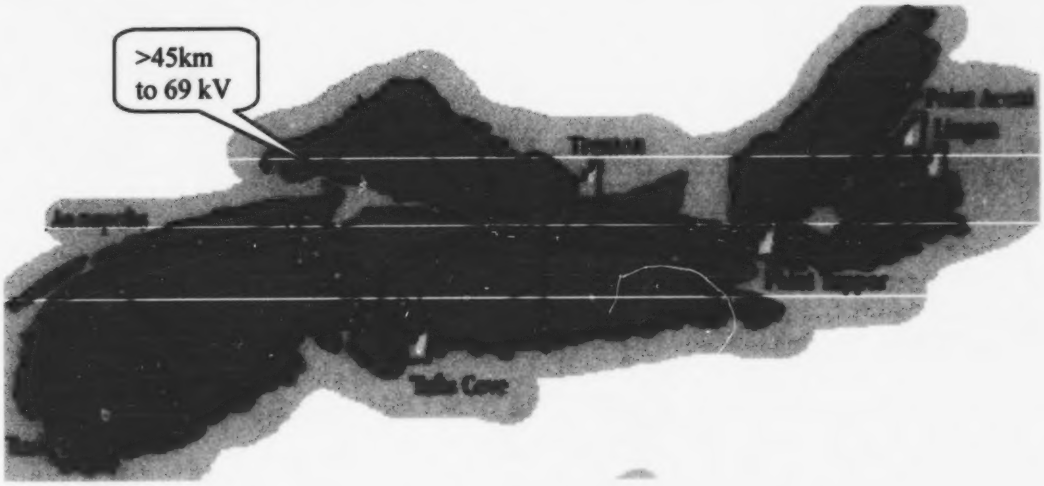

Figure 5.2.8. Distance from Site to Closest 69 kV connection

5.2.3. Maritime Support Infrastructure

Appendix B provides information about marine support services and fabricators in Nova Scotia. As detailed there, a wide variety of shipyards and offshore marine contractors exists is the Halifax-Dartmouth area, well suited for fabrication and assembly of TISEC devices.

For shoreside support services (inspection, maintenance, and repair of operating devices), the nearest city with an extensive maritime infrastructure is Saint John, New Brunswick,, but this port is located approximately 130 km southwest of Minas Channel. A service vessel traveling at a cruising speed of 12-14 knots (24 KPH) would require a transit time of 4-1/2 hours if going with the current, or 5-1/2 hours if going against the current. At a tow speed of 6-7 knots (12 KPH), the trip would take 9 to 11 hours, depending on timing relative to the tide.

Parrsboro, Nova Scotia, has a well-maintained wharf and is located just inside the Minas Passage, with a water route distance of only 30 km from Minas Channel. A service vessel traveling to Cape d'Or at a cruising speed of 12-14 knots (24 KPH) would require a transit time of 1 hour if going with the current, or 2 hours if going against the current. At a tow speed of 6-7 knots (12 KPH), the trip would take 2 to 4 hours, depending on timing relative to the tide.

Compared to coming from Saint John, a vessel's response time from Parrsboro would be 4 to 5 hours faster for investigating a problem or delivering a service crew to the project site, and would be 7 to 8 hours faster if towing a device. This saves fuel and greatly reduces down time for a device outage incident. It also minimizes exposure to waiting-on-weather delays, compared to a trip that covers half the length of the Bay of Fundy. Moreover, compared to Saint John, the local weather at Parrsboro is much more like the weather in Minas Channel, greatly reducing the risk of unexpected wave or wind conditions found by the service vessel when it arrives on site.

Parrsboro is a stronger candidate than Hantsport to provide shoreside support. See Section 5.1.8 for descriptions of the waterfront facilities in both towns and the reason for this recommendation.

5.2.3. Environmental Considerations

The Cape Split area has recently been declared a Nova Scotia provincial park. Projects to mine the seabed of the Cape Split Sand Wave Field for marine aggregates were first embraced by the provincial and federal governments, but later cancelled by the provincial government.

Tourism and eco-tourism are a growing industry in the region. Although visual impact could be a concern for a device such as the monopile-based Marine Current Turbines, several individuals commented that they would be no more objectionable than an offshore lighthouse, and may have merit as supplemental aids to navigation. Another observation is that when viewed from cliff heights, the surface expression of these devices would appear almost insignificant against the immense scale of the Minas Channel and its bordering coastlines.

5.2.9. Unique Opportunities

Between Minas Channel and Minas Passage, the tidal in-stream energy resource is estimated to be capable of providing a significant contribution to Nova Scotia Power's generating portfolio. If realized, this would have substantial spin-off benefits likely to be supported by regional agencies responsible for economic development and infrastructure provision.

5.3 Minas Passage

Minas Passage connects Minas Channel to Minas Basin and Cobequid Bay. It is a rectangular body of water that trends northwest-to-southeast, with its outer corner points being Ram Head and Cape Split, and its inner corner points being Cape Blomidon and Parrsboro Harbour, as shown in Figure 5.3-1, below

MINAS PASSAGE

Figure 5.3-1. Geographic landmarks for Minas Passage (Reference 6).

5.3.1. *Tidal In-Stream Energy Resource*

Potential project transects in Minas Passage are shown in Figure 5.3-2, below. Also shown are nearby locations where measured current data exist, archived in the Ocean Data Inventory (ODI) maintained by the Department of Fisheries and Oceans Canada.

ODI Series Designation	Latitude (deg N)	Longitude (deg W)	Depth (m)	Series Start Date & End Date	Series Duration
MCM_65017_75_27_300	45.3633	64.6166	10	08 Aug – 23 Aug 65	15 days
MCM_76014_13_1197_600	45.3383	64.2933	7	21 May – 24 Jun 76	34 days
MCM_76007_13_1196_600	45.3383	64.2933	28	21 May – 25 Jun 76	35 days
MCM_74052_43a_306_360	45.3	64.245	16	18 Jul – 05 Sep 74	49 days

Figure 53.3-2. Aerial photograph from an altitude of approximately 30 km, showing the numerically modeled transects in Minas Passage (Reference 6).

5.3.1. Tidal In-Stream Energy Resource

Potential project transects in Minas Passage are shown in Figure 5.3-2, below. Also shown are nearby locations where measured current data exist, archived in the Ocean Data Inventory (ODI) maintained by the Department of Fisheries and Oceans Canada.

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MCM_74052_43a_306_360	45.3	64.245	16	18 Jul – 05 Sep 74	49 days

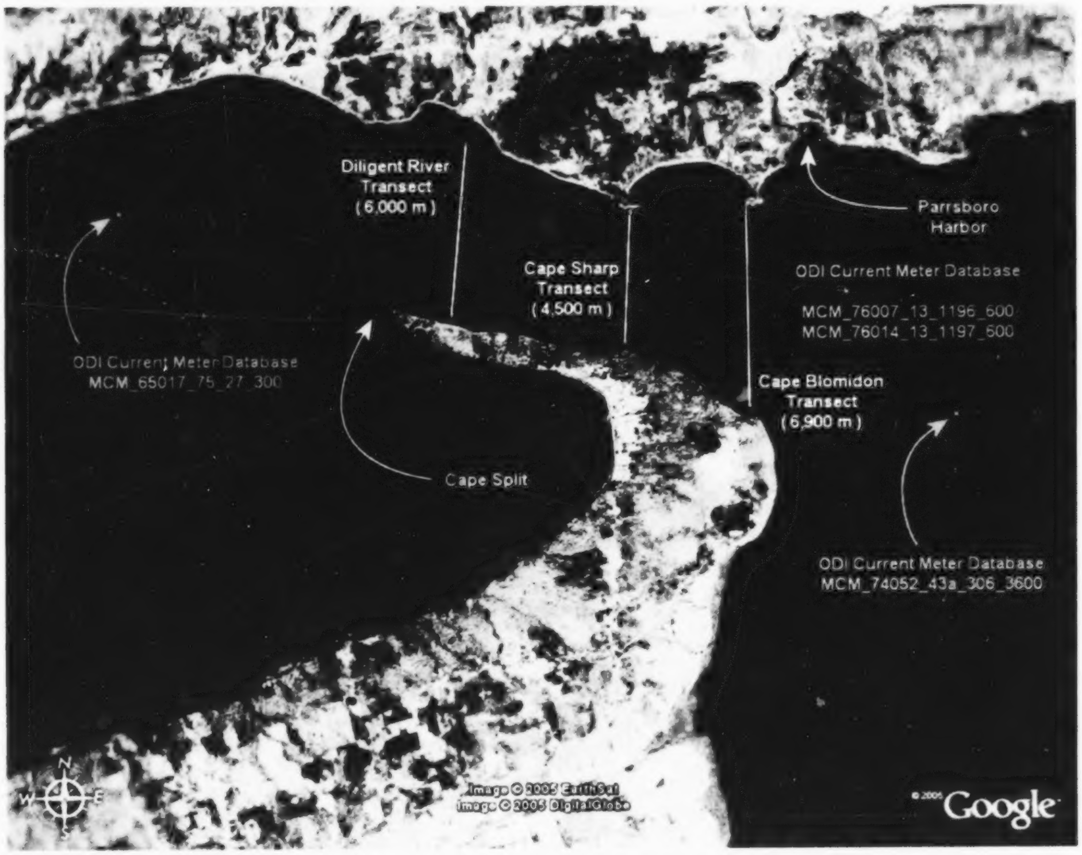
Diligent River Transect (6,000 m)
Cape Sharp Transect (4,500 m)
Parrsboro Harbor
ODI Current Meter Database
MCM_76007_13_1196_600
MCM_76014_13_1197_600
ODI Current Meter Database
MCM_65017_75_27_300
Cape Blomidon Transect (6,900 m)
Cape Split
ODI Current Meter Database
MCM_74052_43a_306_3600
N
W
E
S
Image © 2005 EarthSat
Image © 2005 DigitalGlobe
© 2005 Google

Figure 53.3-2. Aerial photograph from an altitude of approximately 30 km, showing the numerically modeled transects in Minas Passage (Reference 6).

CHS chart #4010 shows that the fastest currents of 7 to 8 knots are in the southern part of Minas Passage, close by Cape Split (Figure 5.3-3). Lesser current velocities of 5 to 6 knots are found on the north side, off Ram Head and Cape Sharp. Farther to the west, as Minas Passage opens into Minas Basin, peak tidal current speeds drop to 4 knots. The calculation below uses 6 knots, as the channel-wide average peak current velocity, which corresponds to a peak tidal stream power density of 15 kW/m^2 at the surface.

Assuming that the time series profile of tidal stream velocity can be approximated by a sinusoidal curve, then the time-averaged velocity over one tidal period would be 63.7% of the peak velocity. Moreover, the mean value of the velocity-cubed over one tidal period would be 42.4% of the peak velocity cubed. Since tidal in-stream power density is proportional to velocity cubed, then the mean power density averaged over an entire tidal period would be 42.4% of 15 kW/m^2, which is 6.4 kW/m^2.

Since this is based on the surface velocity, it needs to be adjusted to estimate the depth-averaged tidal stream power density. Assuming that a 1/10-power law approximates the decrease in velocity from the surface to the bottom of the channel, then the depth-averaged value of velocity cubed would be 76.9% of its surface value. This yields a depth-averaged tidal stream power density of 11.5 kW/m^2 for peak ebb and flood currents, and 4.9 kW/m^2 averaged over time.

The cross-sectional area of the Cape Sharp transect (see Figure 5.3-2) is reported by Reference 2 to be 226,400 m^2, giving a total resource base of 1,109,400 kW. Withdrawing 15% of this power yields an extractable resource of 166,400 kW. Assuming a "water to wire" conversion efficiency of 80% and a project capacity factor of 40%, then the maximum tidal in-stream capacity that could be installed at this site is 332,800 kW.

It should be noted that this value is substantially higher than the value estimated for Minas Channel. In part this is probably due to the much greater cross-channel variability of tidal current speeds in Minas Channel, causing the use of a channel-wide average velocity to under-estimate the average value of velocity-cubed.

Some of this difference also may be due to the different degree to which tidal stream energy is dissipated in eddies between these two sites. According to the *Atlas of Tidal Currents* for the Bay of Fundy and Gulf of Maine (Reference 3), the eddy that forms off Scots Bay, on the ebb tide past Cape Split, is much larger, vigorous, and persistent than the eddy that forms off Greville Bay on the flood tide past Cape Spencer. Thus one might expect the tidal stream energy flux through Minas Passage to have a larger net value.

Given that the estimated potential total tidal in-stream capacity in Minas Channel (262 MW) or Minas Passage (333 MW) corresponds to a significant fraction of Nova Scotia Power's total installed capacity (2,300 MW), it is critical that the flow through these channels be modeled and measured in detail.

5.3.2 Seafloor Bathymetry and Geology

A hydrographic chart of the Cumberland Basin entrance is given below.

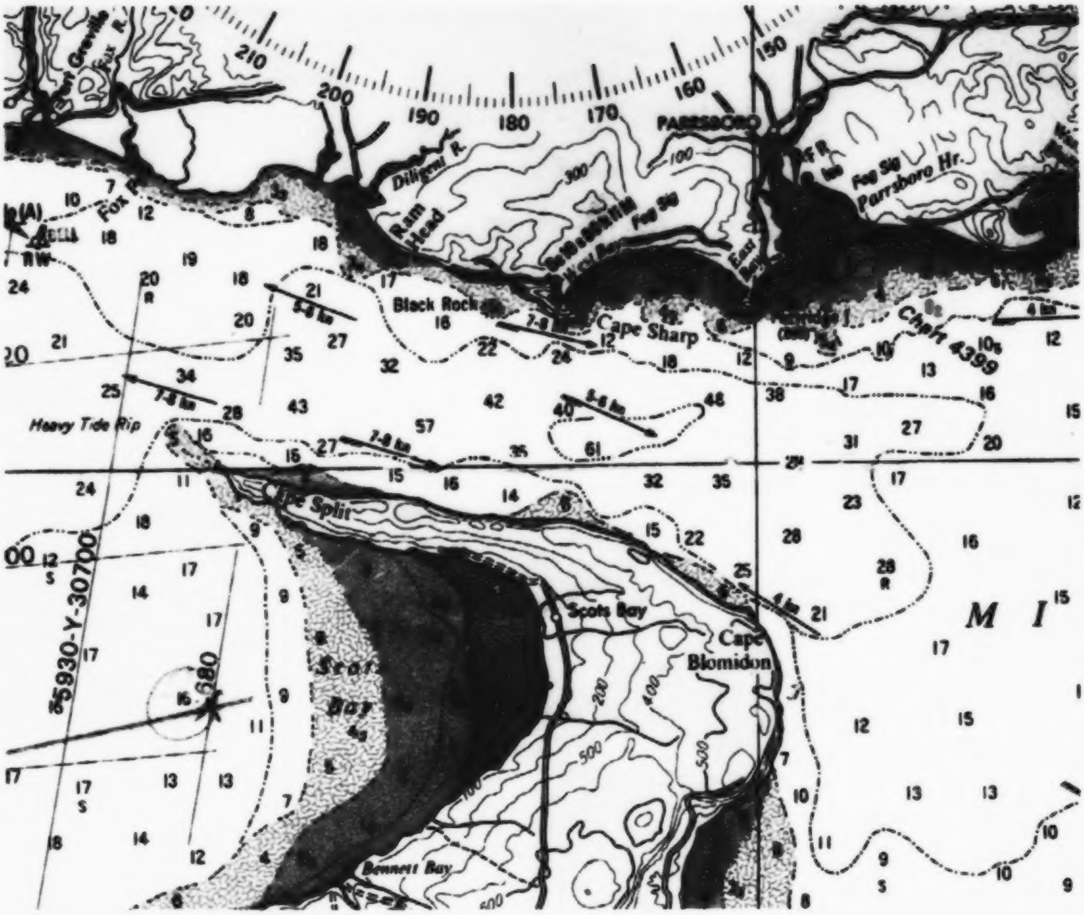
210
200
190
180
170
160
150
PARRSBORO
Diligent R.
Fox R.
Ram Head
Parrsboro Hr.
Black Rock
Cape Sharp
Chart 4399
Heavy Tide Rip
Cape Split
Scots Bay
Cape Blomidon
Bennett Bay
5930-Y-30700
680
M I

Figure 5.3-3. Scanned section of CHS chart #4010 for Minas Passage. Depths are in fathoms, with additional feet as subscript (1 fathom = 6 ft = 1.8 m).

5.3.2 Seafloor Bathymetry and Geology

A hydrographic chart of the Cumberland Basin entrance is given below.

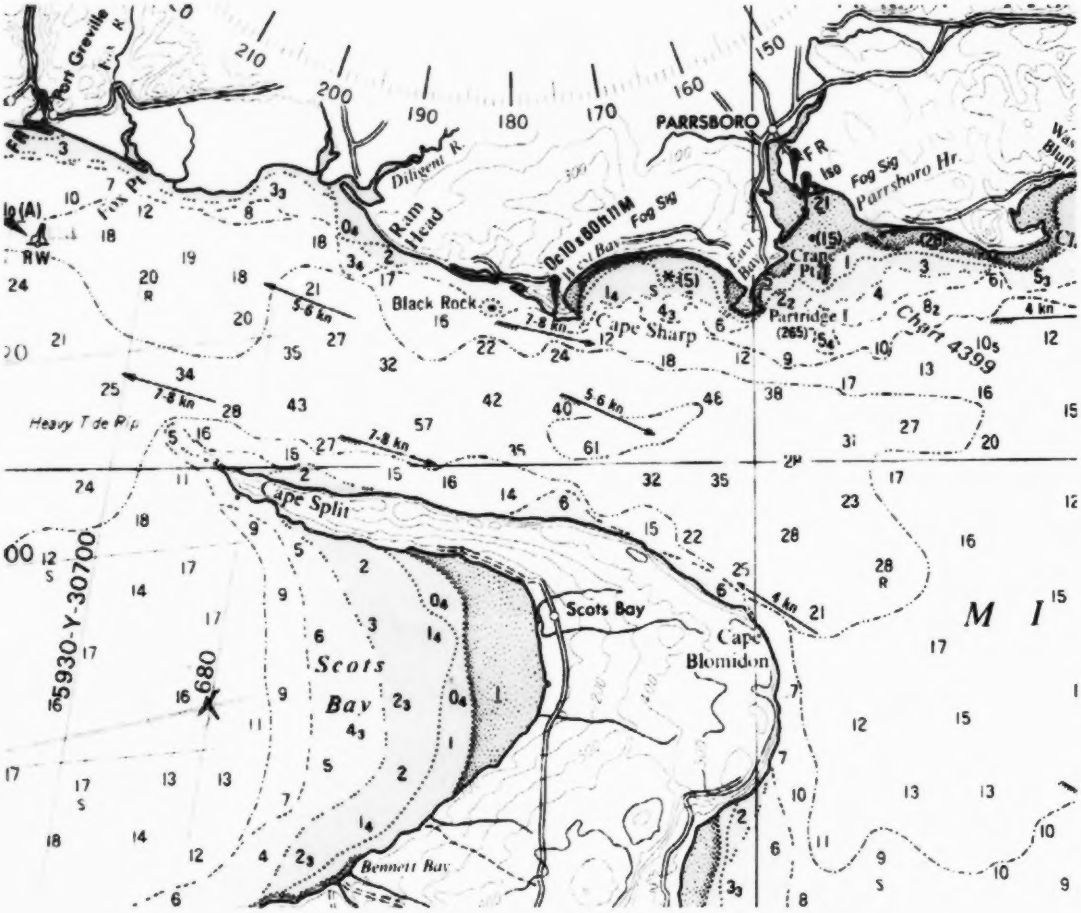
Port Greville
Fox Pt
Diligent R.
Ram Head
PARRSBORO
West Bay
East Bay
Parrsboro Hr.
Fog Sig
Black Rock
Cape Sharp
Crane Pt.
Partridge I.
Chart 4399
Heavy Tide Rip
Cape Split
Scots Bay
Scots Bay
Cape Blomidon
Bennett Bay
5930-Y-30700
680
M I
210
200
190
180
170
160
150
7-8 kn
5-6 kn
4 kn

Figure 5.3-3. Scanned section of CHS chart #4010 for Minas Passage. Depths are in fathoms, with additional feet as subscript (1 fathom = 6 ft = 1.8 m).

Seismic reflection and sidescan sonar surveys have been undertaken in Minas Passage to support bedrock mapping and the earlier tidal power assessment in the 1960s and 1970s.

Minas Passage is underlain mostly by Triassic sedimentary bedrock, but a long, linear volcanic deposit occurs parallel to the passage just south of the north shore and is mapped as the Triassic McKay Head Basalt. As shown in Figure 5.3-4, almost the entire seafloor of Minas Passage is exposed bedrock, with gravel deposits close to shore on either side.

The bathymetry shows a long linear deep depression in the middle of Minas Passage with water depths over 100 m (Figure 5.3-5).

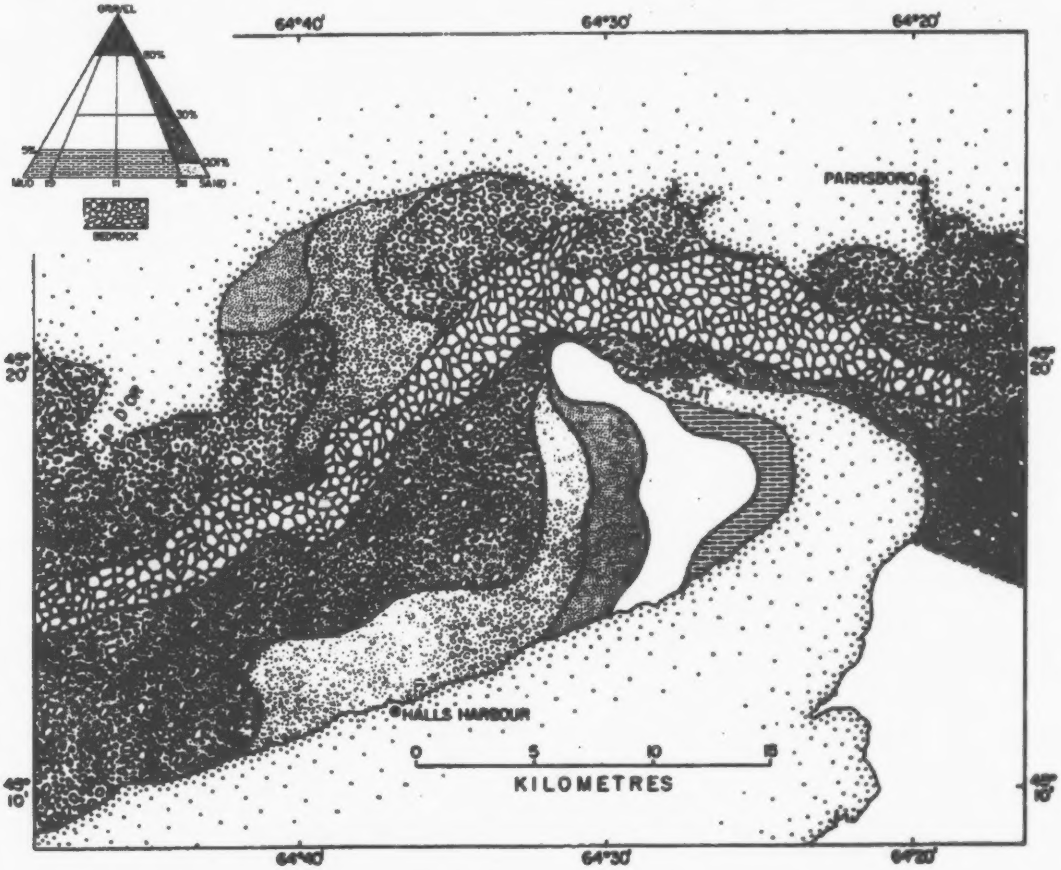
GRAVEL
80%
30%
5%
30%
MUD
SAND
BEDROCK
64°40'
64°30'
64°20'
45°20'
45°10'
CAPE D'OR
PARRSBORO
HALLS HARBOUR
0
5
10
15
KILOMETRES

Figure 5.3-4. Sediment and bedrock distribution in Minas Channel and Minas Passage.

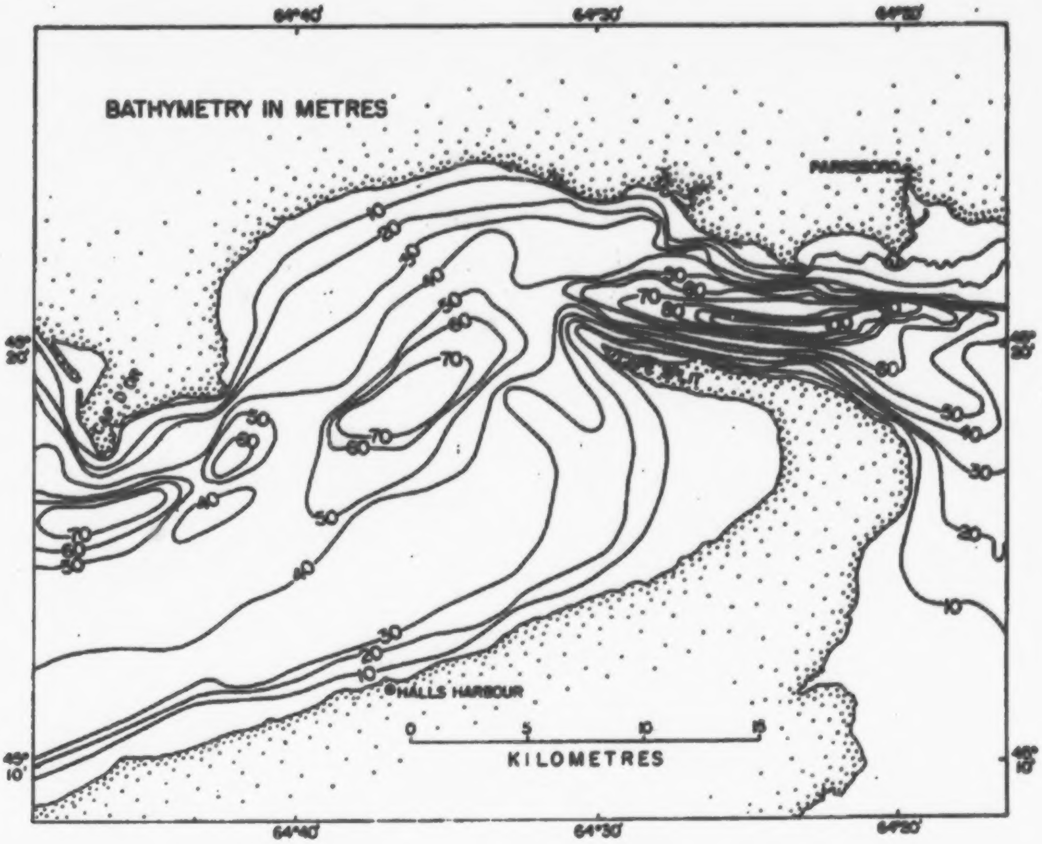
64°40'
64°30'
64°20'
BATHYMETRY IN METRES
PARRSBORO
CAPE D'OR
CAPE SPLIT
HALLS HARBOUR
45°20'
45°10'
10
20
30
40
50
60
70
80
0
5
10
15
KILOMETRES

Figure 5.3-5. Bathymetric contour map of Minas Channel and Minas Passage.

There is only one small area at the entrance to Minas Passage that has been surveyed with multibeam bathymetry, which is the survey over a large sand deposit west of Cape Split described in the previous section, but it also continues into Minas Passage and provides information within the deep depression that can be extrapolated throughout the passage.
To the north of the sand wave field, the multibeam data is from the western part of the deep channel area. The seabed shows as a series of sub-parallel ridges interpreted to be outcropping bedrock. They trend more or less west to east. Some features appear to be normal to the direction of the ridges and the strong currents of the area suggest that they may represent gravel bedforms. A detailed interpretation of the multibeam bathymetric imagery integrated with the sample and seismic information is essential for a better understanding of morphology, features and processes in Minas Passage.

5.3.3 Utility Grid Interconnection

Interconnection to the NSPI grid is shown in Figure 5.3-7 for 25 kV and Figure 5.3-8 for 69 kV.

Pilot Demonstration Scale 1MW Tidal Installation - Rough Order of Magnitude for Transmission Interconnection:

For Distribution Level Interconnection to the South of Partridge Island (not including any Submarine Cabling) for an approximately 1 MW unit, the Rough Order of Magnitude costing would be $475,000.

The next phase in developing this costing is to initiate a "Preliminary Review" at a nominal cost. This is a more formal high level look at a distributed generation site, and is required before a System Impact Study can be performed. The Preliminary Review would provide required circuit upgrades, expected electrical ratings and characteristics at the site after circuit upgrades are complete, summary of system assets in the affected sites and cost estimate.

Commercial Scale - 350MW Tidal Installation - Rough Order of Magnitude for Transmission Interconnection:

An initial look at a 350 MW tidal project in the area of the Cape Sharp Transect confirmed that such a project would have a significant impact on the reliability and operation of the Nova Scotia and potentially the Maritimes power system.

The proposed site sits in an area that would impact the Nova Scotia - New Brunswick interconnection and therefore a joint study by NSPI and NBSO would be required. The import-export capability of this interconnection would be preserved, and if required, enhanced by the transmission reinforcement required for the TISEC Installation.

The "Order of Magnitude of Probable Cost" is $200,000,000 which would consist of 345KV Transmission, substations and reactor/capacitor banks required to maintain conformance with Transmission standards. It should also be noted that the future state of system development can have a large influence on this value in the open access development configuration.

A full System Impact Study would be required to proceed with assessment of the installations impact to the power system. Transmission access is provided on a first-come, first-served basis, up to the Available Transfer Capability of the transmission path of interest, under Open Access development mechanisms.

NSPI, as do all transmission operators in North America, design and operate the power systems to criteria and standards established by the North American Electric Reliability Council (NERC) and its affiliated regional council Northeast Power Coordinating Council (NPCC). As the System Study is completed, it would be published on the NSPI public Open Access Same-time Information System (OASIS) in accordance with our Standards of Conduct, and the project would be reviewed by NPCC.

A full System Impact Study would address the following issues at a minimum:

1. Develop a valid computer model of the TISEC generation and prime-mover equipment and controls.
2. Review the expected operational characteristics: controllability, ability to schedule, etc. of the technology

3. Review potential power quality issues (flicker, harmonics, resonance) if non-conventional technology is proposed.
4. Develop alternative interconnection options
5. Evaluate the steady-state and transient performance of the interconnected power system for all NPCC standard and extreme contingencies (load flow and stability studies)
6. Evaluate the impact of multiple units comprising 350 MW installation on NS reserve requirements.
7. Evaluate the ability to maintain equipment with a minimum of disruption to production, while still meeting NPCC criteria.
8. Potential for plant to provide ancillary services (tie line control, frequency control, reserve) particularly with high penetration of wind energy conversion systems in NS.
9. Recommend least-cost configuration meeting system reliability requirements.

Generator interconnection and procedures for requesting transmission access (firm or non-firm) for both NSPI and NBSO can be found at oasis.nspower.ca and www.nbso.ca.
A full System Impact Study and Facilities study would cost in the order of $150,000 and take 12 months to complete.

Figure 5.3-6 Distance from Site to closest 25 kV connection

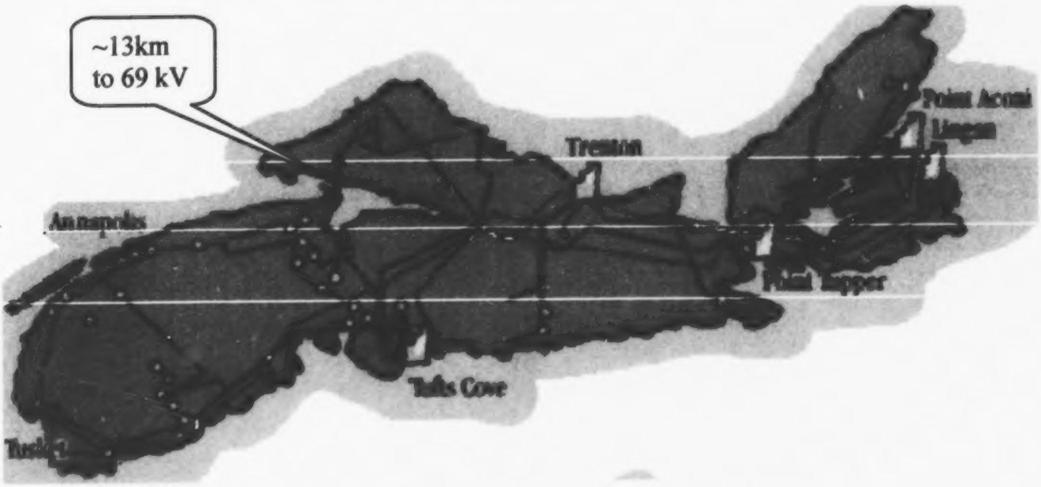

Figure 5.3-7. Distance from Site to closest 69 kV connection

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Appendix B provides information about marine support services and fabricators in Nova Scotia. As detailed there, a wide variety of shipyards and offshore marine contractors exists is the Halifax-Dartmouth area, well suited for fabrication and assembly of TISEC devices.

For shoreside support services (inspection, maintenance, and repair of operating devices), the nearest city with an extensive maritime infrastructure is Saint John, New Brunswick,, but this port is located approximately 130 km southwest of Minas Passage. A service vessel traveling at a cruising speed of 12-14 knots (24 KPH) would require a transit time of 4-1/2 hours if going with the current, or 5-1/2 hours if going against the current. At a tow speed of 6-7 knots (12 KPH), the trip would take 9 to 11 hours, depending on timing relative to the tide.

Parrsboro, Nova Scotia, has a well-maintained wharf and is located just inside the Minas Passage. A service vessel traveling to Cape Split at a cruising speed of 12-14 knots (24 KPH) would require a transit time of less than an hour if going with the current, or 1-1/2 hours if going against the current. At a tow speed of 6-7 knots (12 KPH), the trip would take 1 to 3 hours, depending on timing relative to the tide.

Compared to coming from Saint John, a vessel's response time from Parrsboro would be 5 to 6 hours faster for investigating a problem or delivering a service crew to the project site, and would be 8 to 9 hours faster if towing a device. This saves fuel and greatly reduces down time for a device outage incident. It also minimizes exposure to waiting-on-weather delays, compared to a trip that covers half the length of the Bay of Fundy. Moreover, compared to Saint John, the local weather at Parrsboro is virtually identical to that in Minas Passage, greatly reducing the risk of unexpected wave or wind conditions found by the service vessel when it arrives on site.

Parrsboro is a stronger candidate than Hantsport to provide shoreside support. See Section 5.1.8 for descriptions of the waterfront facilities in both towns and the reason for this recommendation.

5.3.4. Environmental Considerations

The Cape Split area has recently been declared a Nova Scotia provincial park. Projects to mine the seabed of the Cape Split Sand Wave Field for marine aggregates were first embraced by the provincial and federal governments, but later cancelled by the provincial government.

Tourism and eco-tourism are a growing industry in the region. Although visual impact could be a concern for a device such as the monopile-based Marine Current Turbines, several individuals commented that they would be no more objectionable than an offshore lighthouse, and may have merit as supplemental aids to navigation. Another common remark is that when viewed from cliff heights, the surface expression of these devices would appear almost insignificant against the immense scale of the Minas Passage and its bordering coastlines.

5.3.5. Unique Opportunities

Between Minas Channel and Minas Passage, the tidal in-stream energy resource is estimated to be capable of providing a significant contribution to Nova Scotia Power's generating portfolio. If realized, this would have substantial spin-off benefits likely to be supported by regional agencies responsible for economic development and infrastructure provision.

5.4 Cobequid Bay

Cobequid Bay is located in the inner area of Minas Basin and is a smaller body of shallow water at the head of the basin. Minas Basin is a triangular-shaped body of water over 74 km long that tapers from 28 km wide at its entrance to 7 km wide at the entrance to Cobequid Bay. The entrance to Cobequid Bay is considered to be the narrow area between Economy Point on the north shore and Cape Tenny on the south shore (see Figures 5.4-1 and 5.4-2).

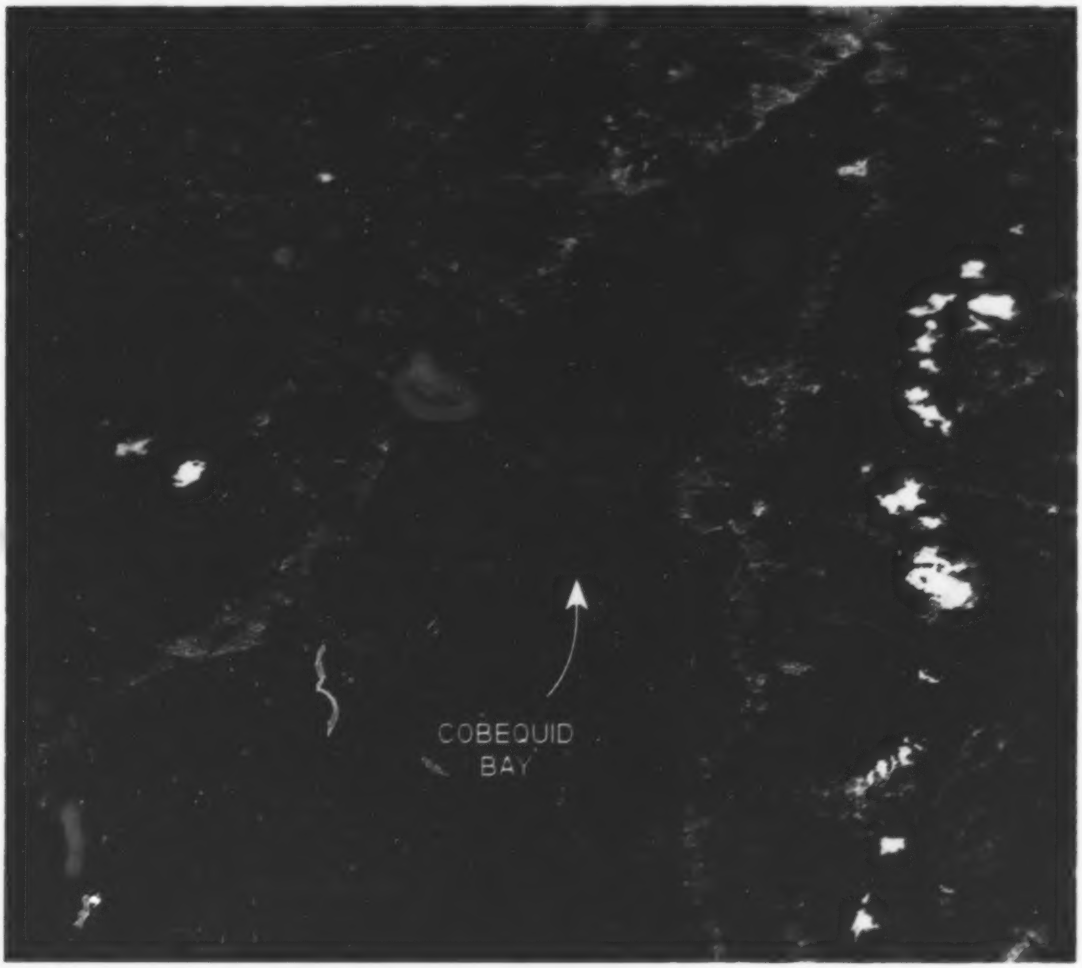

Figure 5.4-1. Geographic landmarks for Cobequid Bay (Reference 6).

5.4.1. Tidal In-Stream Energy Resource

The narrowest transect at the entrance to Cobequid Bay is shown in Figure 5.4-2, below. There are no measured current data for this site archived in the Ocean Data Inventory (ODI) maintained by the Department of Fisheries and Oceans Canada.

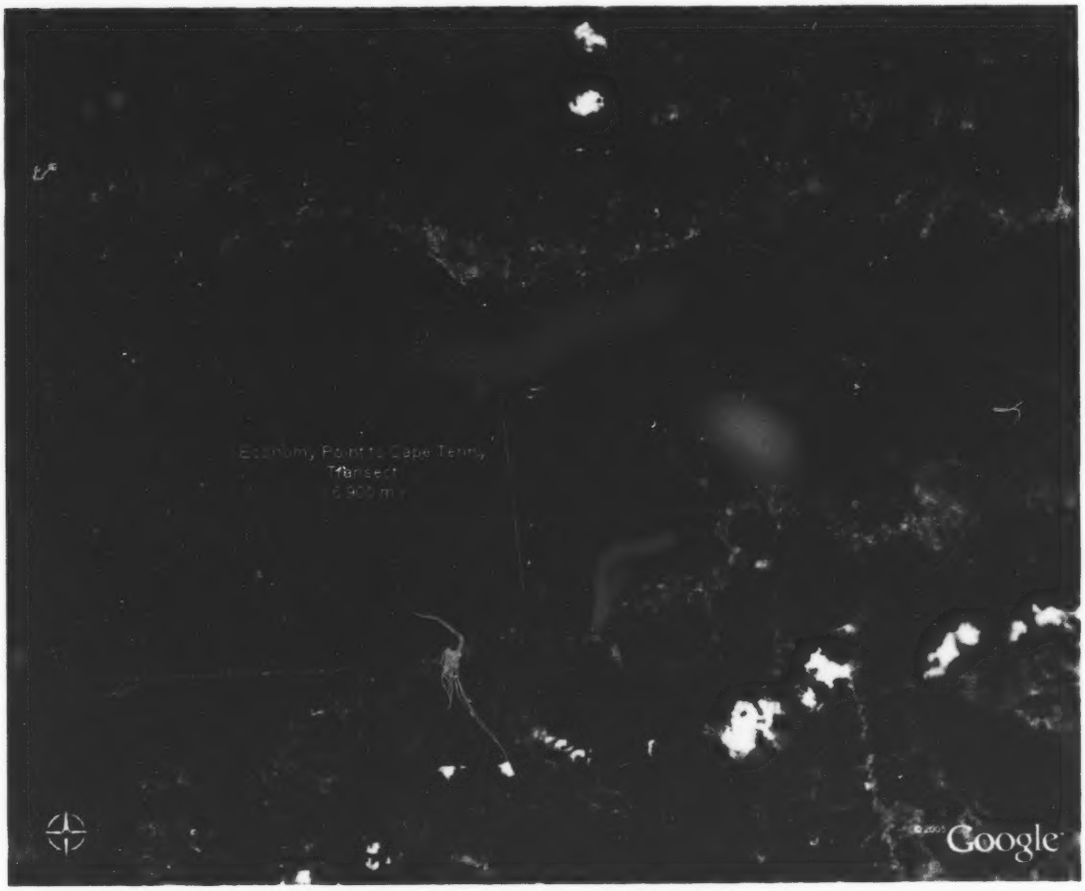

Figure 5.4-2. Aerial photograph from an altitude of approximately 20 miles, showing the numerically modeled transect in Cobequid Bay (Reference 6).

CHS chart #4010 shows peak tidal current velocities of 4 knots in both directions occurring in the narrowest area off Economy Point, close by the north shore. Somewhat lesser current speeds of 3 knots occur close by the south shore (Figure 5.4-3). The calculation below uses 3.5 knots, as the average peak current velocity, which corresponds to a peak tidal stream power density of 3.0 kW/m^{2}at the surface.

Assuming that the time series profile of tidal stream velocity can be approximated by a sinusoidal curve, then the time-averaged velocity over one tidal period would be 63.7% of the peak velocity. Moreover, the mean value of the velocity-cubed over one tidal period would be 42.4% of the peak velocity cubed. Since tidal in-stream power density is proportional to velocity cubed, then the mean power density averaged over an entire tidal period would be 42.4% of 3.0 kW /m^2, which is 1.3 kW/m^2.

Since this is based on the surface velocity, it needs to be adjusted to estimate the depth-averaged tidal stream power density. Assuming that a 1/10-power law approximates the decrease in velocity from the surface to the bottom of the channel, then the depth-averaged value of velocity cubed would be 76.9% of its surface value. This yields a depth-averaged tidal stream power density of 2.3 kW/m^2 for peak ebb and flood currents, and 1.0 kW/m^2 averaged over time.

The cross-sectional area of the Economy Point transect (see Figure 5.8-2) is reported by Reference 2 to be 42,200 m^2, giving a total resource base of 42,200 kW. Withdrawing 15% of this power yields an extractable resource of 6,300 kW. Assuming a "water to wire" conversion efficiency of 80% and a project capacity factor of 40%, then the maximum tidal in-stream capacity that could be installed at this site is 12,700 kW.

It is interesting to note that this is the same potential capacity as estimated for the entrance to Cumberland Basin, which has about half the cross-sectional area, but a channel-wide average peak surface current velocity of 2.3 m/sec (4.5 knots), as compared with 1.8 m/sec (3.5 knots) for the entrance to Cobequid Bay.

5.4.2. Seafloor Bathymetry and Geology

A hydrographic chart showing the entrance to Cobequid Bay is given below.

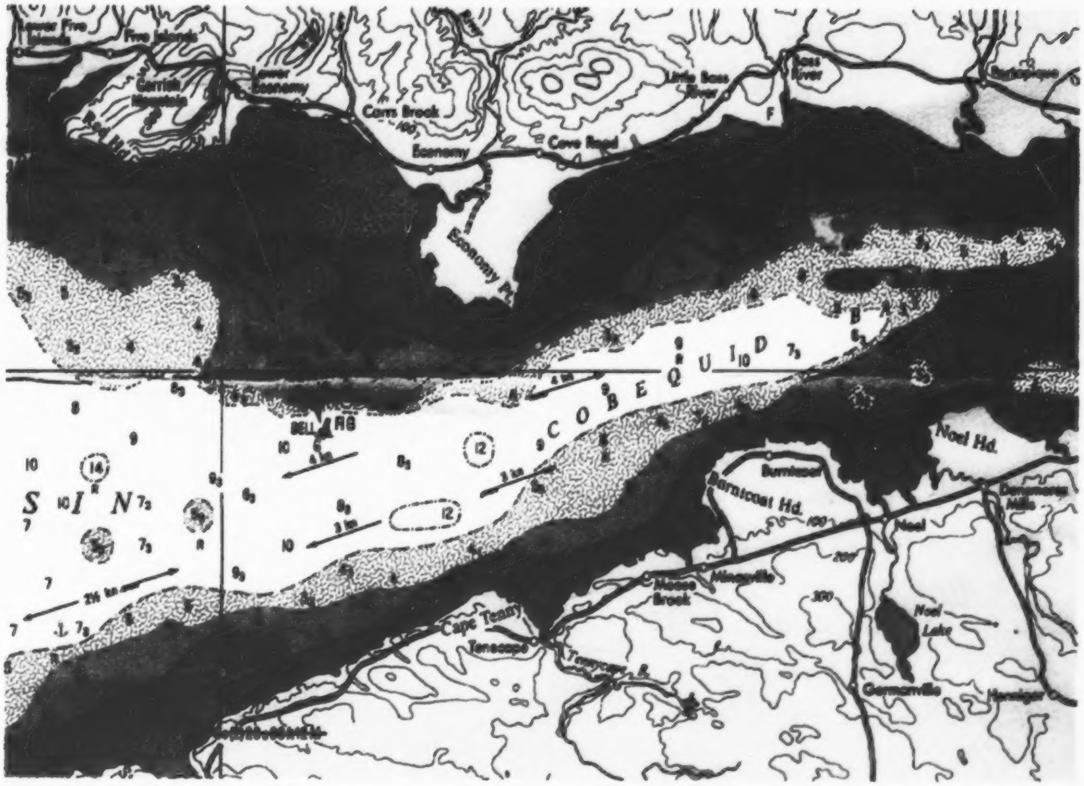
Five Islands
Lower Economy
Carrs Brook
Economy
Cove Road
Little Bass River
Bass River
Economy Pt.
C O B E Q U I D
BELL RG
M I N A S
Noel Hd.
Burntcoat Hd.
Noel
Minasville
Moose Brook
Cape Tenny
Tenecape
Noel Lake
Gormanville

Figure 5.4-3. Scanned section of CHS chart #4010 for Cobequid Bay. Depths are in fathoms, with additional feet as subscript (1 fathom = 6 ft = 1.8 m).

5.4.2. Seafloor Bathymetry and Geology

A hydrographic chart showing the entrance to Cobequid Bay is given below.

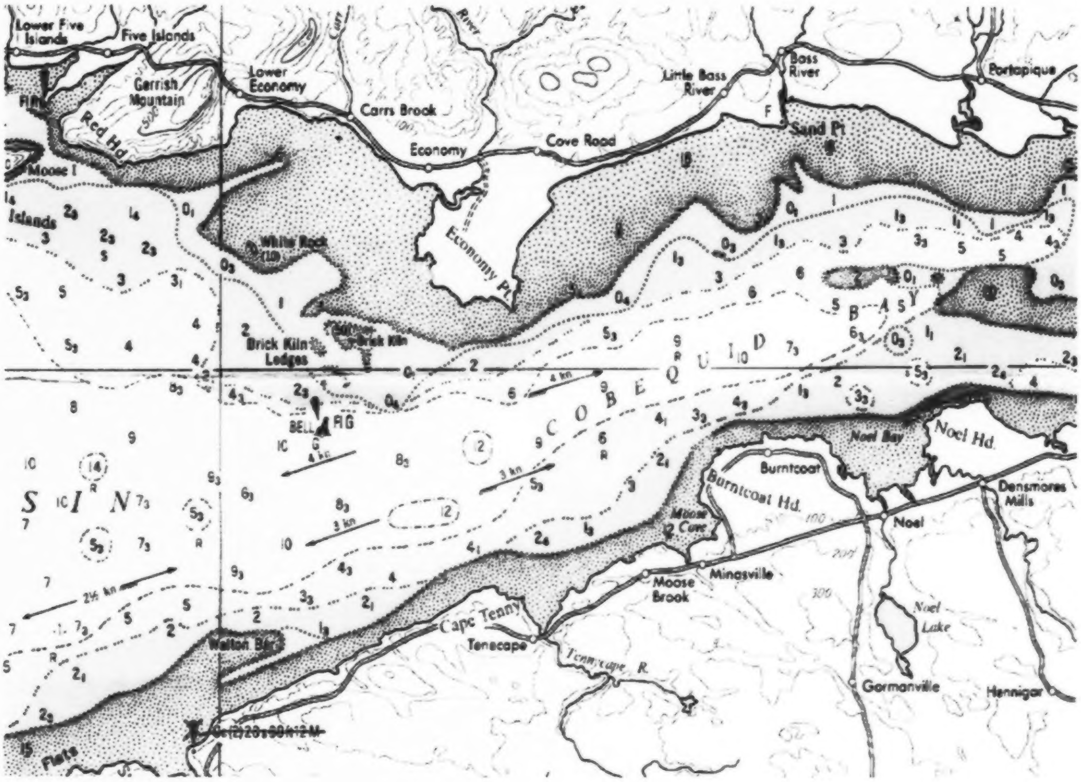
Lower Five Islands
Five Islands
Gerrish Mountain
Red Hd
Moose I
Islands
Lower Economy
Carrs Brook
Economy
Cove Road
Little Bass River
Bass River
Portapique
Sand Pt
Economy Pt
White Rock
Brick Kiln Ledges
BELL
COBEQUID BAY
S I N
Noel Bay
Noel Hd
Burntcoat
Burntcoat Hd
Densmores Mills
Noel
Moose Cove
Minasville
Moose Brook
Cape Tenny
Tenecape
Tennycape R.
Walton Bar
Noel Lake
Gormanville
Hennigar
Flats
4 kn
3 kn
2½ kn

Figure 5.4-3. Scanned section of CHS chart #4010 for Cobequid Bay. Depths are in fathoms, with additional feet as subscript (1 fathom = 6 ft = 1.8 m).

As with the other potential project sites in the upper Bay of Fundy, Cobequid Bay was studied as part of early tidal power barrage sites in the 1960s and 70s and geological surveys have been conducted to investigate oceanographic conditions, sediment distribution and transport, adjacent cliff recession and seabed surficial geology. Two tidal barrage sites were explored in Cobequid Bay, and the final chosen one was between Economy Point and Cape Tenny, referred to as B9 (Reference 7).

A number of vibrocores and drill cores of bedrock were collected across Cobequid Bay for the early tidal power barrage construction evaluation. The location for the section extends from Economy Point to Cape Tenny (Figure 5.4-4).

The bedrock under Cobequid Bay is Triassic sedimentary rock, consisting of red sandstone and conglomerate, part of the Wolfville and Blomidon Formations. In the crossection off Economy Point, the bedrock dips to the north and several faults occur beneath the Bay, particularly near its geographic centre. The crossection shows the bedrock surface to be at or near the seabed on the southern side (Figure 5.4-5).

The thickest sediments occur in the centre of the crossection and are approximately 15 m thick. The average thickness is 6.1 m feet or less. A regional roughness of the seabed over a large area, as seen on the three crossing profiles, suggests that the morphology may result from the presence of sand bedforms or scour features cut into the seabed. This is not clear from the crossection, and sidescan sonograms and/or multibeam bathymetry need to be collected for verification.

Figure 5.4-5 also shows two additional crossections 66 m to the east and west of the main crossing from Economy Point to Cape Tenny. They show similar bedrock distributions but with differing relief and shape on the bedrock surface as well as thicknesses of surficial sediments. These adjacent profiles suggest that unlike the entrance to Cumberland Basin, the seafloor geology is not uniform across the entrance to Cobequid Bay.

A map of seafloor sediments (Figure 5.4-6) shows that the bottom is mostly a sandy gravel ranging to a gravelly sand, with sand occurring closer to the north and south shores.

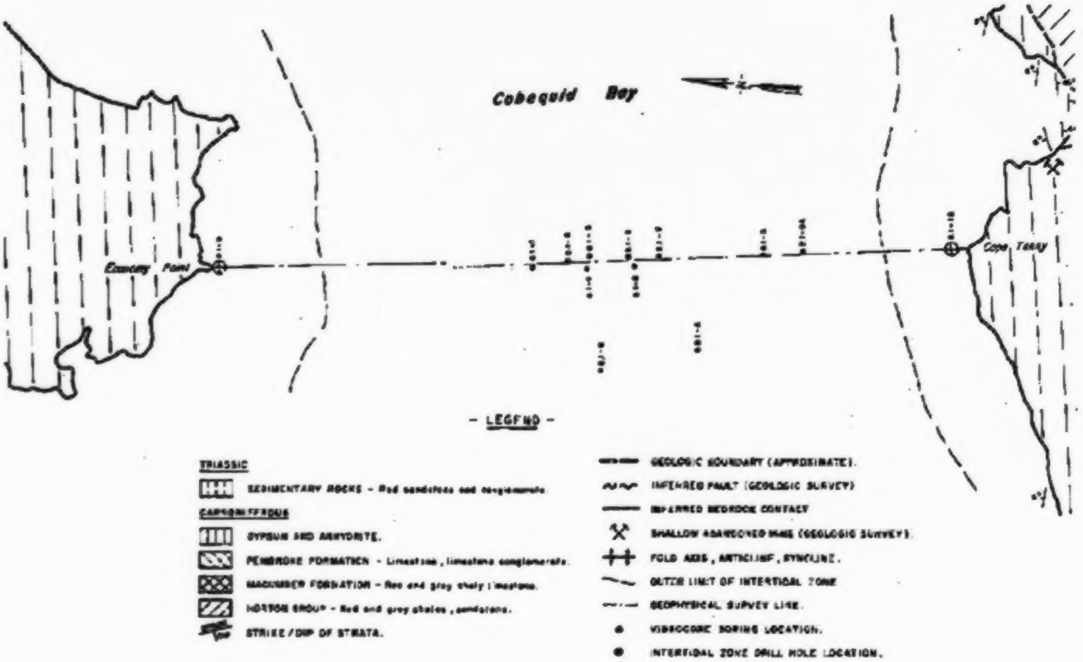
Cobequid Bay
Economy Point
Cape Tenny
- LEGEND -
TRIASSIC
SEDIMENTARY ROCKS - Red sandstone and conglomerate.
CARBONIFEROUS
GYPSUM AND ANHYDRITE.
PEMBROKE FORMATION - Limestone, limestone conglomerate.
MACUMBER FORMATION - Red and grey shaly limestone.
HORTON GROUP - Red and grey shales, sandstone.
STRIKE / DIP OF STRATA.
GEOLOGIC BOUNDARY (APPROXIMATE).
INFERRED FAULT (GEOLOGIC SURVEY)
INFERRED BEDROCK CONTACT
SHALLOW ABANDONED MINE (GEOLOGIC SURVEY).
FOLD AXIS, ANTICLINE, SYNCLINE.
OUTER LIMIT OF INTERTIDAL ZONE
GEOPHYSICAL SURVEY LINE.
VIBROCORE BORING LOCATION.
INTERTIDAL ZONE DRILL HOLE LOCATION.

Figure 5.4-4. Geophysical survey at the entrance to Cobequid Bay, between Economy Point and Cape Tenny.

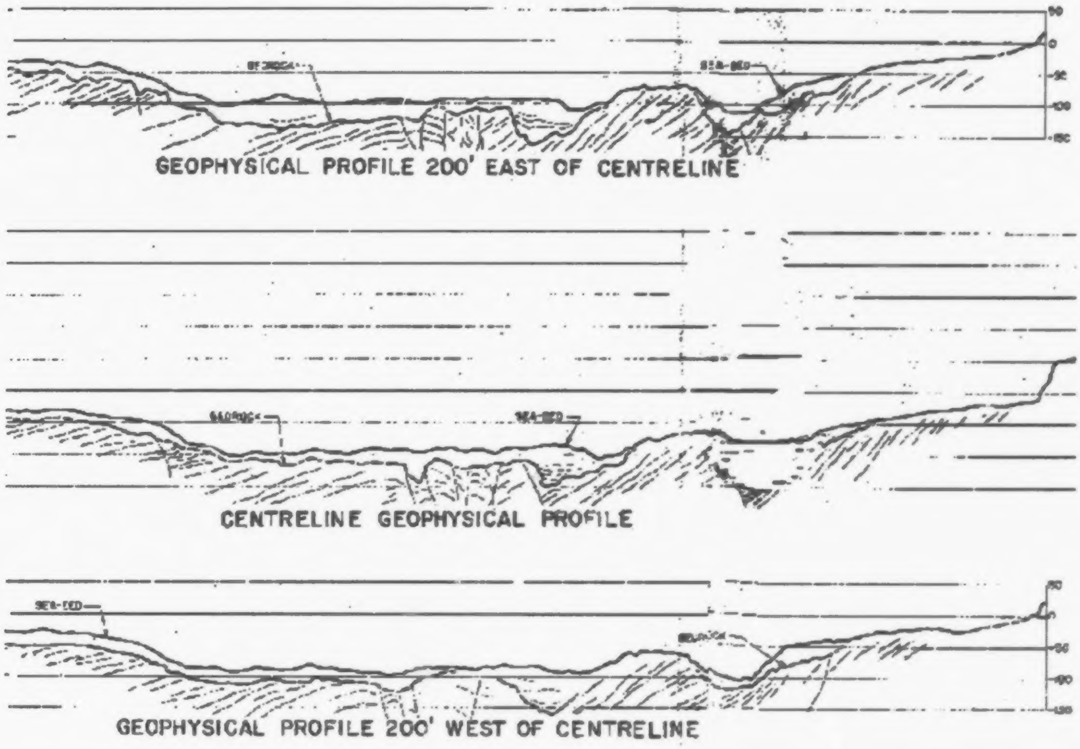
50
0
-50
-100
-150
BEDROCK
SEA-BED
GEOPHYSICAL PROFILE 200' EAST OF CENTRELINE
BEDROCK
SEA-BED
CENTRELINE GEOPHYSICAL PROFILE
SEA-BED
BEDROCK
50
0
-50
-100
-150
GEOPHYSICAL PROFILE 200' WEST OF CENTRELINE

Figure 5.4-5. Three channel cross-sections at the entrance to Cobequid Bay, suggesting that seafloor geology is locally quite variable.

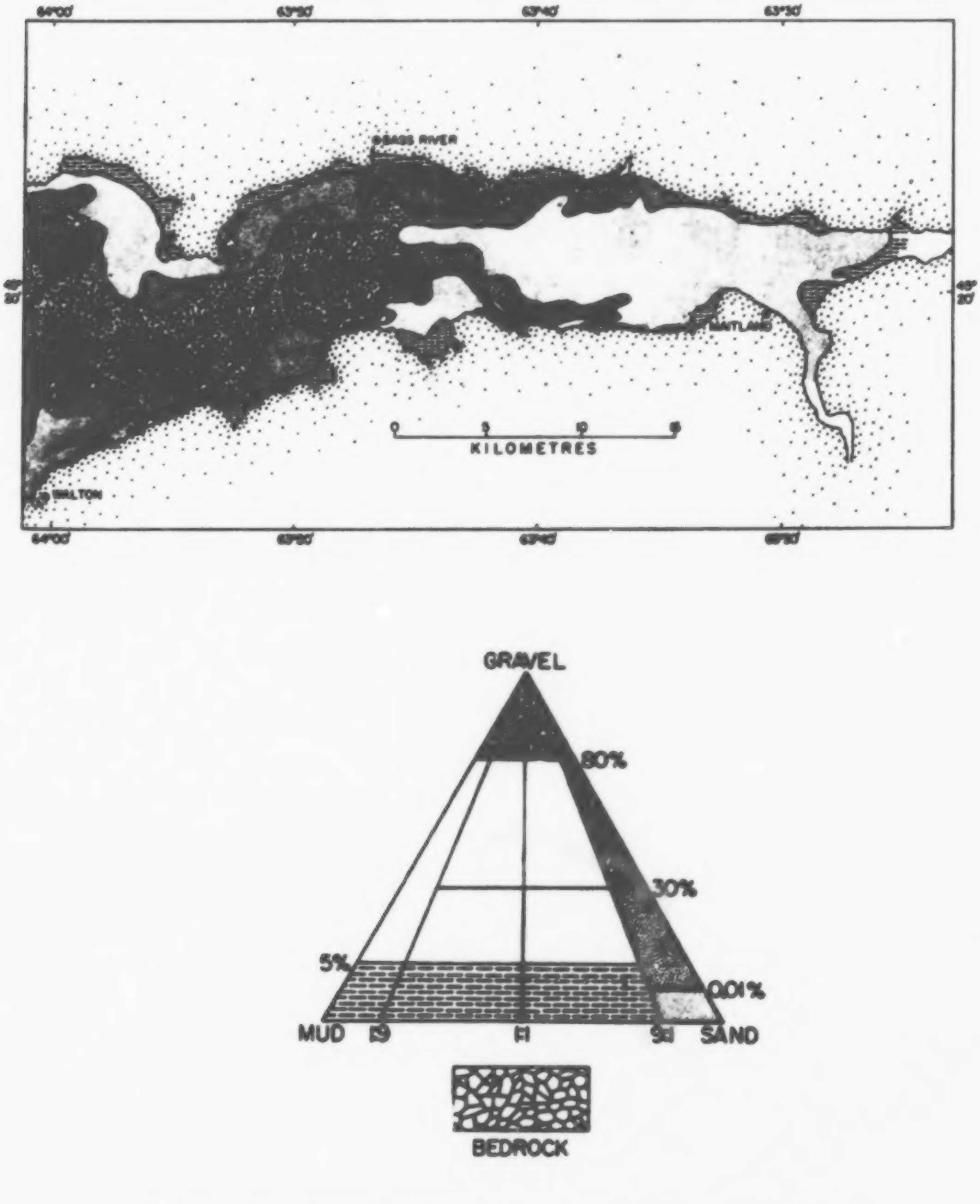
64°00'
63°50'
63°40'
63°30'
45° 20'
BASS RIVER
MAITLAND
WALTON
0
5
10
15
KILOMETRES
GRAVEL
80%
30%
5%
0.01%
MUD
1:9
1:1
9:1
SAND
BEDROCK

Figure 5.4-6. Sediment and bedrock distribution in Cobequid Bay.

5.4.3. Utility Grid Interconnection

Interconnection to the NSPI grid is shown in Figure 5.4-7 for 12 kV and Figure 5.4-8 for 69 kV.

For the 12 kV connection, the distance is estimated to be about 6.4 km

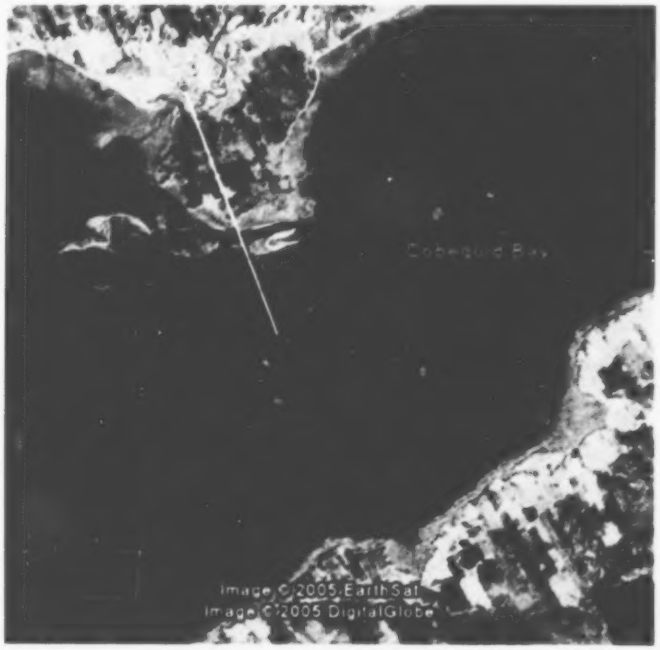
Cobequid Bay
Image © 2005 EarthSat
Image © 2005 DigitalGlobe

Figure 5.4-7 Distance from Site to closest 12 kV connection

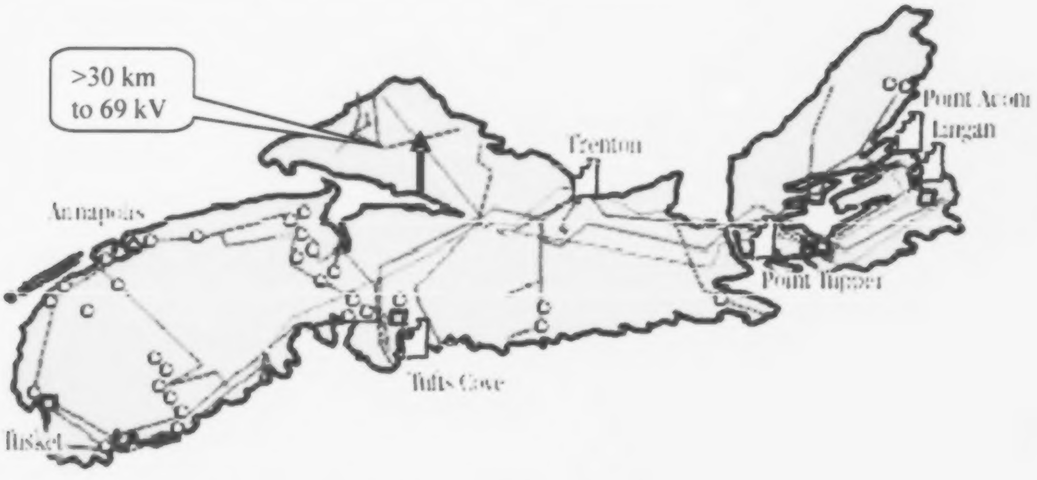
>30 km
to 69 kV
Point Aconi
Lingan
Trenton
Annapolis
Point Tupper
Tufts Cove
Tusket

Figure 5.4-8 Distance from Site to closest 69 kV connection

5.4.3. Utility Grid Interconnection

Interconnection to the NSPI grid is shown in Figure 5.4-7 for 12 kV and Figure 5.4-8 for 69 kV.

For the 12 kV connection, the distance is estimated to be about 6.4 km

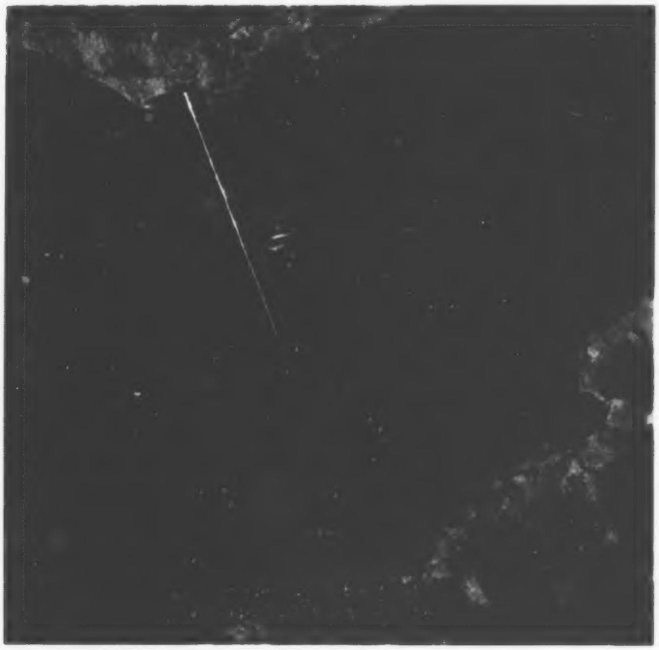

Figure 5.4-7 Distance from Site to closest 12 kV connection

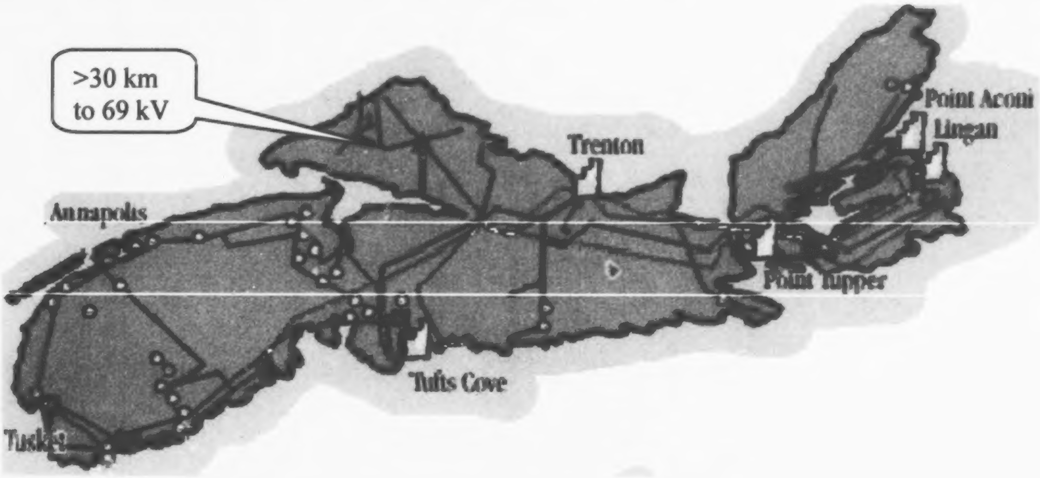
>30 km
to 69 kV
Point Aconi
Lingan
Trenton
Annapolis
Point Tupper
Tufts Cove
Tusket

Figure 5.4-8 Distance from Site to closest 69 kV connection

5.4.3. Maritime Support Infrastructure

Appendix B provides information about marine support services and fabricators in Nova Scotia. As detailed there, a wide variety of shipyards and offshore marine contractors exists is the Halifax-Dartmouth area, well suited for fabrication and assembly of TISEC devices.

For shoreside support services (inspection, maintenance, and repair of operating devices), the nearest city with an extensive maritime infrastructure is Saint John, New Brunswick,, but this port is located approximately 150 km southwest of Cobequid Bay. A service vessel traveling at a cruising speed of 12-14 knots (24 KPH) would require a transit time of 5 hours if going with the current, or 6 hours if going against the current. At a tow speed of 6-7 knots (12 KPH), the trip would take 10 to 12 hours, depending on timing relative to the tide. It should be noted

Parrsboro, Nova Scotia, has a well-maintained wharf and is located just inside the Minas Passage. A service vessel traveling to Cape Split at a cruising speed of 12-14 knots (24 KPH) would require a transit time of less than an hour if going with the current, or 1-1/2 hours if going against the current. At a tow speed of 6-7 knots (12 KPH), the trip would take 1 to 3 hours, depending on timing relative to the tide.

Compared to coming from Saint John, a vessel's response time from Parrsboro would be 6 to 7 hours faster for investigating a problem or delivering a service crew to the project site, and would be 9 to 10 hours faster if towing a device. This saves fuel and greatly reduces down time for a device outage incident. It also minimizes exposure to waiting-on-weather delays, compared to a trip that covers half the length of the Bay of Fundy. Moreover, compared to Saint John, the local weather at Parrsboro is virtually identical to that in Minas Passage, greatly reducing the risk of unexpected wave or wind conditions found by the service vessel when it arrives on site.

Parrsboro is a stronger candidate than Hantsport to provide shoreside support. See Section 5.1.8 for descriptions of the waterfront facilities in both towns and the reason for this recommendation.

5.4.4. Environmental Considerations

Most environmental concerns around Cobequid Bay concern the expansion of residential housing developments around Truro. The tidal bores on the Shubenacadie and Salmon Rivers, both of which empty into Cobequid Bay, are important tourist attractions, and it will be important to show that any TISEC project will not adversely affect these bores.

5.5 Digby Gut

Digby Gut is the name for the passage that joins the Bay of Fundy to Annapolis Basin (see Figure 5.5-1, below). Digby Gut is approximately 4 km long and 0.75 km wide at its narrowest point. Note that two tidal barrages were proposed for the Digby Gut area during the earlier tidal power studies, one at the mouth and the other at the joint area with Annapolis Basin. North America's only operating tidal power plant, owned and operated by Nova Scotia Power Inc., is located at Annapolis Royal.

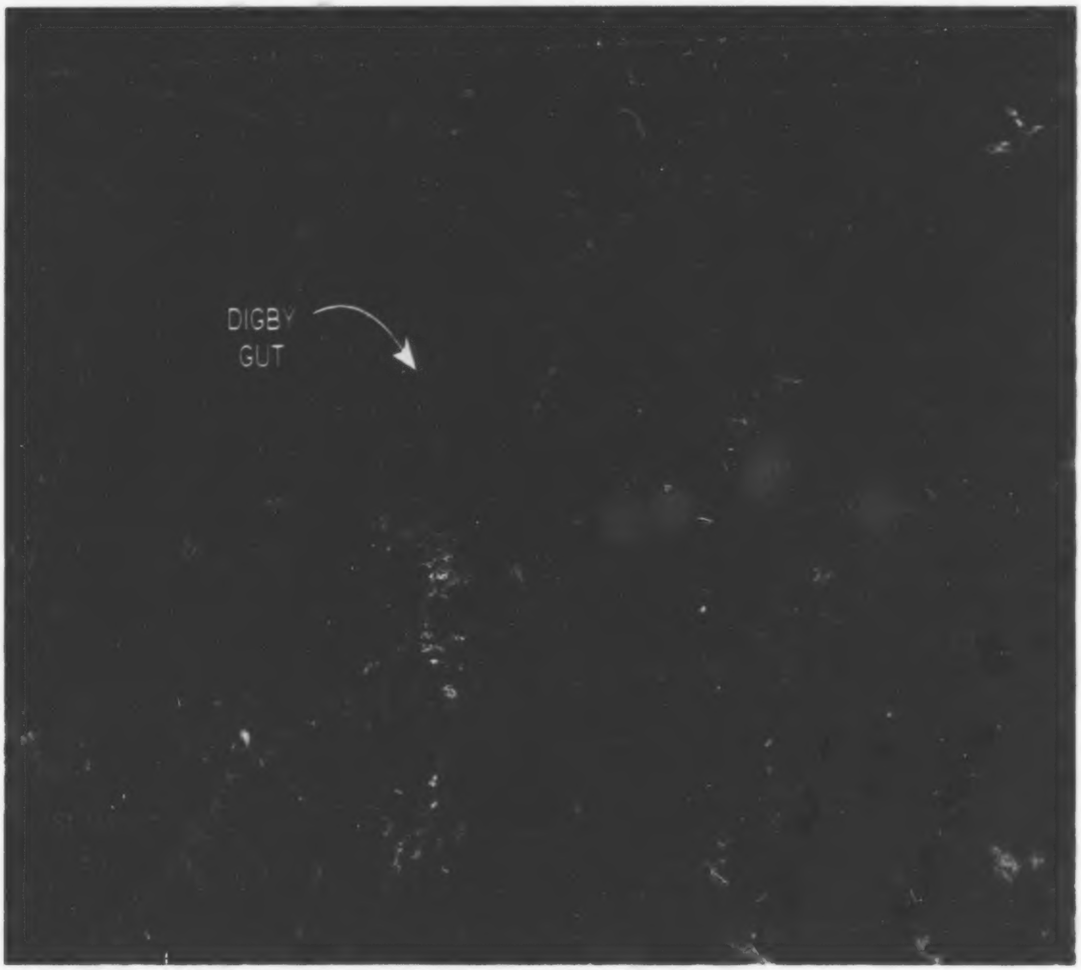

Figure 5.5-1. Geographic landmarks for Digby Gut (Reference 6).

5.5.1. Tidal In-Stream Energy Resource

The narrowest transect in Digby Gut is shown in Figure 5.5-2, below. There are no measured current data for this site archived in the Ocean Data Inventory (ODI) maintained by the Department of Fisheries and Oceans Canada.

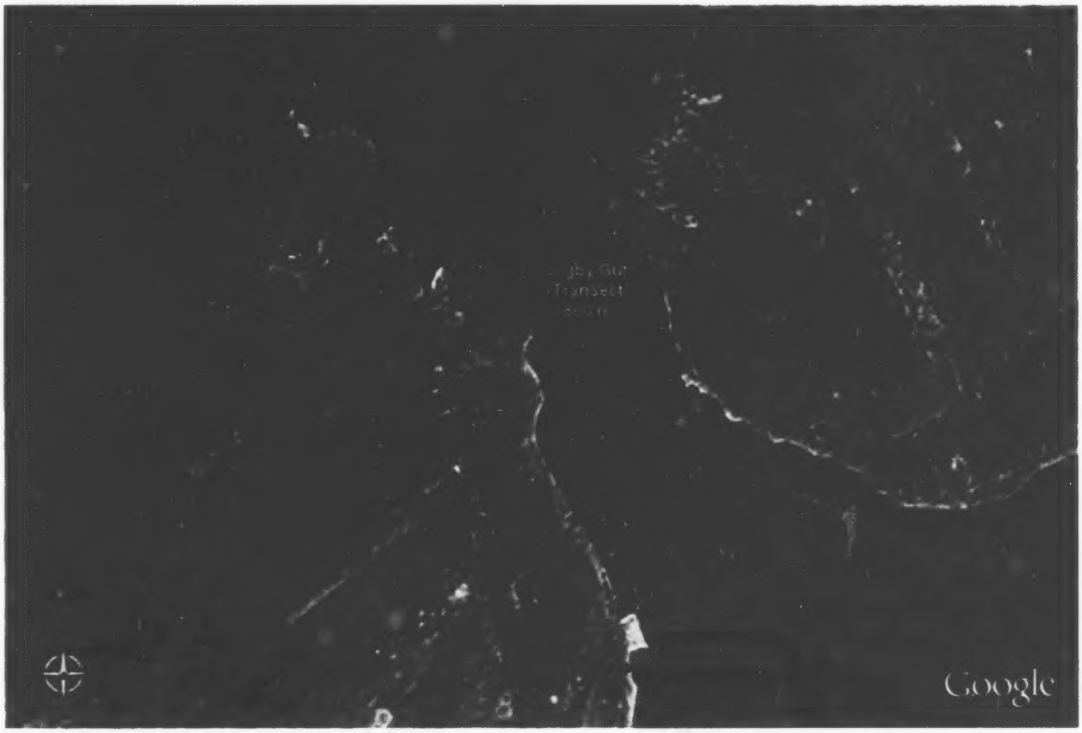

Figure 5.5-2. Aerial photograph from an altitude of approximately 6 km, showing the numerically modeled transect in Cumberland Basin (Reference 6).

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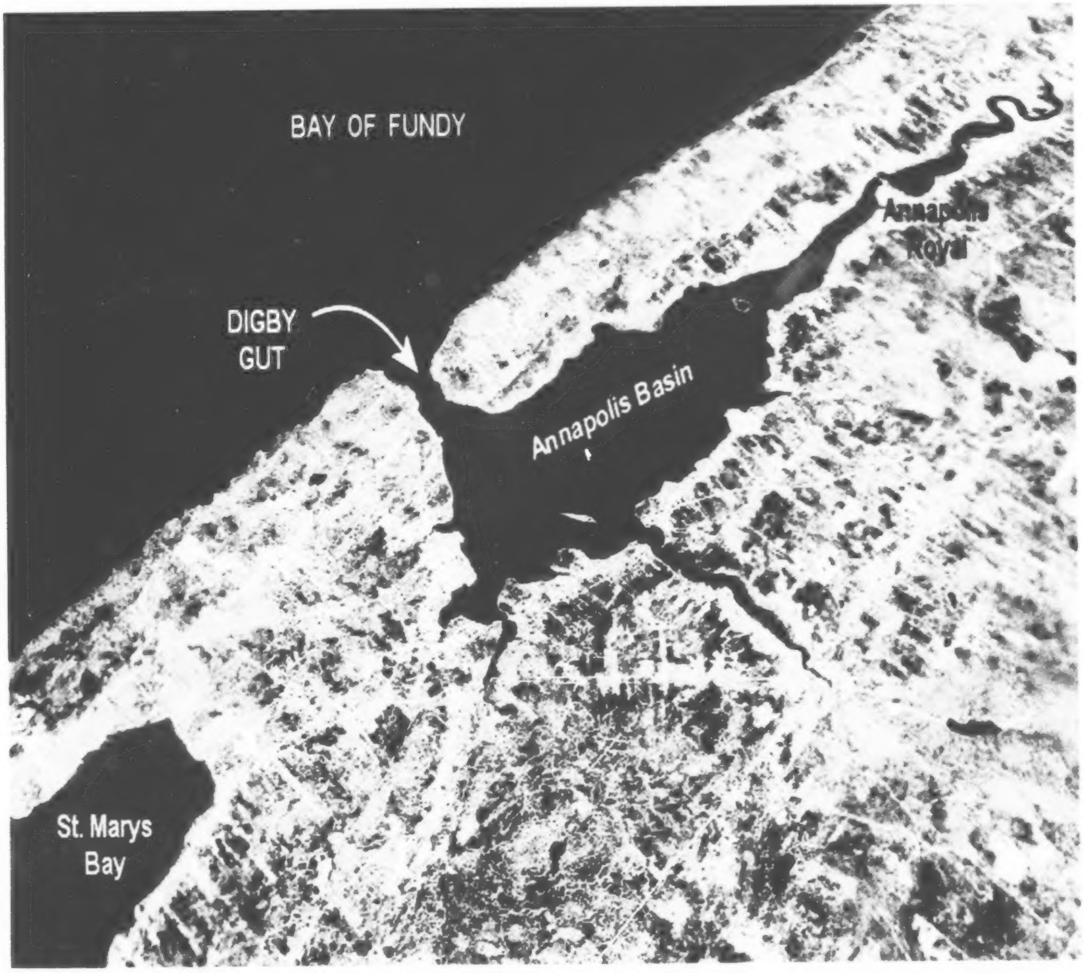

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5.5.1. Tidal In-Stream Energy Resource

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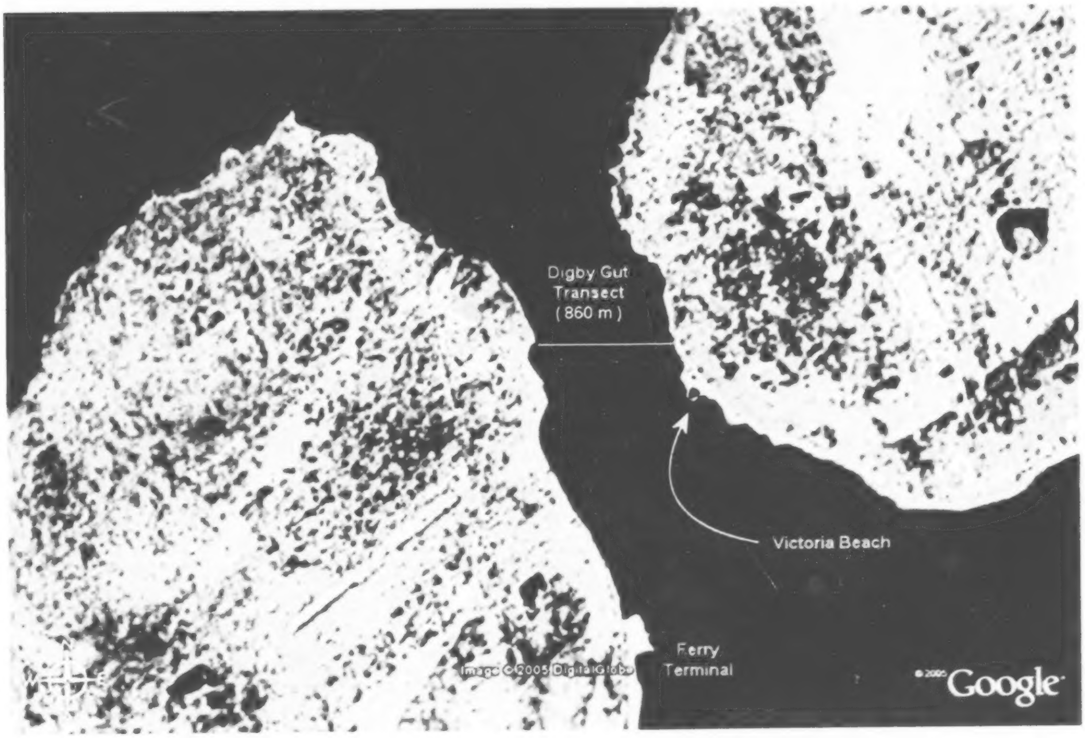
Digby Gut
Transect
(860 m)
Victoria Beach
Ferry
Terminal
Image © 2005 DigitalGlobe
© 2005 Google

Figure 5.5-2. Aerial photograph from an altitude of approximately 6 km, showing the numerically modeled transect in Cumberland Basin (Reference 6).

CHS chart #4396 (Figure 5.8-3) shows several tidal current vectors within Digby Gut, with speeds noted for spring tide conditions ("Sp" notation beneath vector arrows). At the northern entrance, the vectors show tidal peaks of 4.5 knots in both directions; whereas at its narrowest point, between Man of War Rock and Victoria Beach, speeds of 5 knots are attained. Where Digby Gut opens to Annapolis Basin at its southern end, peak velocities drop to 3 knots. A persistent ebb tide eddy current is noted against the western shore, north of Man of War Rock.

Spring current speeds in the Bay of Fundy typically are 30% to 50% higher than neap current speeds (Reference 8). If 5 knots is the spring current speed, then the neap current speed can be expected to be about 3.6 knots, suggesting an average peak speed of 4.3 knots or 2.2 m/sec, which corresponds to a peak tidal stream power density of 5.5 kW/m^2 at the surface.

Assuming that the time series profile of tidal stream velocity can be approximated by a sinusoidal curve, then the time-averaged velocity over one tidal period would be 63.7% of the peak velocity. Moreover, the mean value of the velocity-cubed over one tidal period would be 42.4% of the peak velocity cubed. Since tidal in-stream power density is proportional to velocity cubed, then the mean power density averaged over an entire tidal period would be 42.4% of 5.5 kW/m^2, which is 2.3 kW/m^2

Since this is based on the surface velocity, it needs to be adjusted to estimate the depth-averaged tidal stream power density. Assuming that a 1/10-power law approximates the decrease in velocity from the surface to the bottom of the channel, then the depth-averaged value of velocity cubed would be 76.9% of its surface value. This yields a depth-averaged tidal stream power density of 4.3 kW/m^2 for peak ebb and flood currents, and 1.8 kW/m^2 averaged over time.

The cross-sectional area of Digby Gut is roughly estimated from the CHS chart to be 18,000 m^2, giving a total resource base of 32,400 kW. Withdrawing 15% of this power yields an extractable resource of 4,900 kW. Assuming a "water to wire" conversion efficiency of 80% and a project capacity factor of 40%, then the maximum tidal in-stream capacity that could be installed at this site is 9,800 kW.

5.5.2. Seafloor Bathymetry and Geology

A hydrographic chart of Digby Gut is given below.

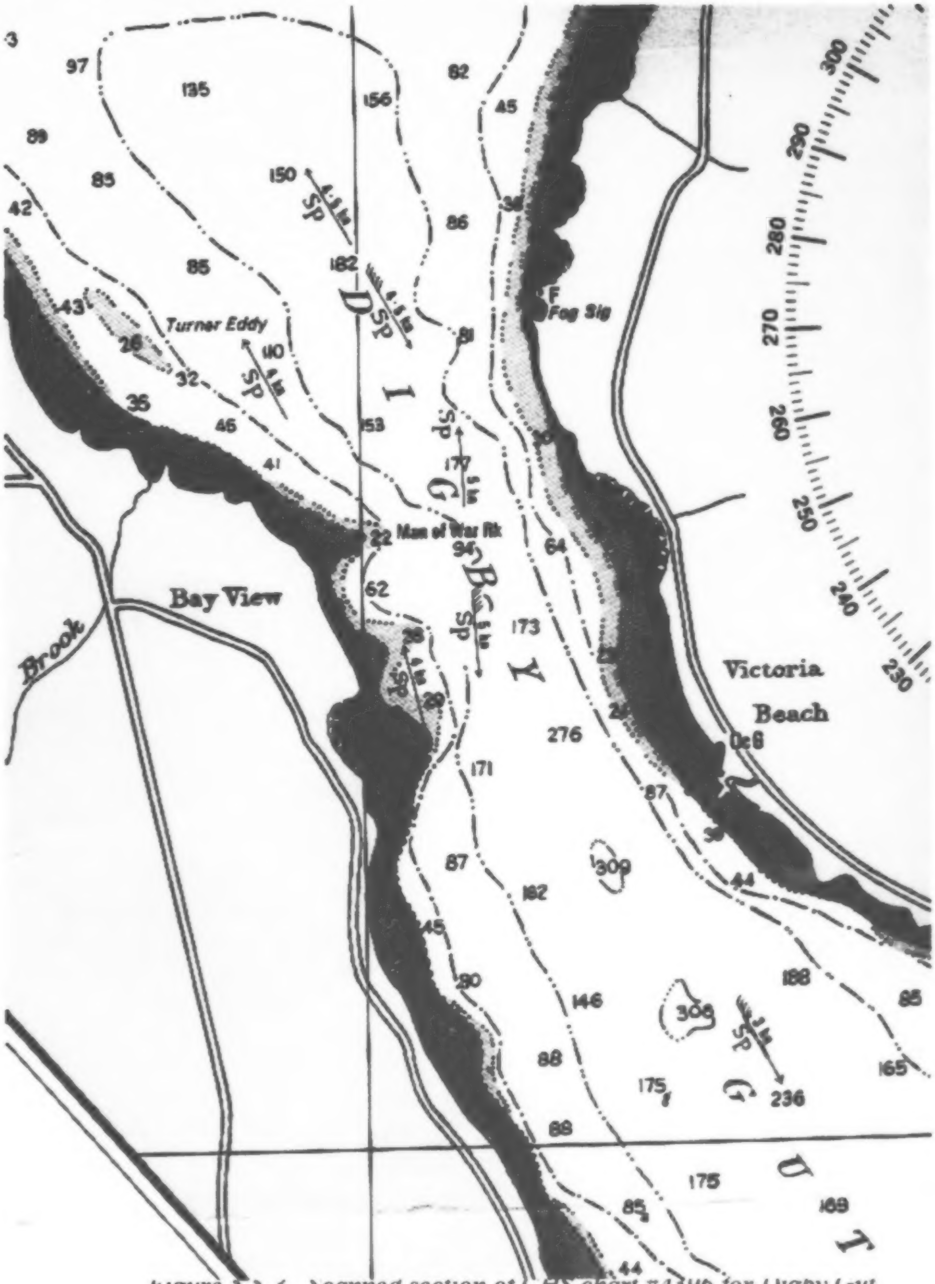
Turner Eddy
Man of War Rk
Bay View
Brook
F
Fog Sig
Victoria
Beach
D
I
G
B
Y
G
U
T
SP
300
290
280
270
260
250
240
230
135
156
150
182
177
173
276
171
309
306
236
175
169
188
165

Figure 5.5-3. Scanned section of CHS chart #4396 for Digby Gut. Depths are in feet (1 ft = 0.3 m).

Digby Gut is notionally marked by the 30 m depth contour but its true shape is not well defined on the bathymetric map. Two deep depressions occur in the southern part of the channel with spot depths of 94 m surrounded by small circular-shaped isolated 300 ft contours. Other spot depths in the channel from north to south are, 135, 150, 182, 173, 276, 236, 169 and the over 300 ft isolated deeps. There appears to be a sill area in the mid channel east of an area termed the Man of War Rock where the water depth is 94 ft. It is deeper than 100 ft in the adjacent, narrow sill area.

North Mountain Formation basalt occurs on either side of the passage and the basalt is interpreted to be continuous across it in the outer part of the gut. Unlike the other passages to the southwest, which are completely underlain by North Mountain Basalt, the southern half of Digby Gut is underlain by considerably softer Triassic siltstone and shale. The passage is interpreted to be fault-controlled and the fault is Jurassic in age and not active.

Similar to the other passages to the southwest, the origin of Digby Gut is interpreted to have initially resulted from the presence of a north-south fault with subsequent movement followed by fluvial and glacial erosion. Digby Neck is offset from North Mountain by 1.3 km to the north as a result of the strike slip movement on the fault. The fault does not appear to continue to the north and there is no deformation in the overlying Triassic/Jurassic sediments further offshore on the seismic reflection profiles.

Surficial sediments have been mapped in the southern part of the gut and consist of gravel waves. They likely overly till in the subsurface. They are fresh in appearance on the multibeam bathymetry and may be active. No fine-grained muds are present. The surficial geology of the northern area of the gut is not known, but exposed bedrock is expected to dominate at the seabed considering the prominent shallow sill and strong currents. If surficial sediments are present, they would be till and covered in lag gravels with boulders.

Multibeam imagery has been collected in only the southern half of Digby Gut, but it reveals unique characteristics of the seabed (Figure 3.5-4). The part of the image to the north is interpreted to represent bedrock exposed at the seabed. There, the image shows flat surfaces with steep and angular areas associated with terraces or slopes. Further south in the Gut, the seabed has a dominant character of overlapping bedforms. They were interpreted as sand waves formed by the strong currents in the gut. The asymmetry of the bedforms suggests that the dominant currents are developed on the flood from the northwest.

Large volume grab samples were collected from the interpreted sand wave field in the gut during surveys of the *C.C.G.S. Hudson*. The sediments turned out not to be sand, but coarse gravel in the pebble, cobble and small boulder size range using the Wentworth grain-size scale. The gravel was very well-rounded. The interpretation therefore has been revised and the bedforms are now considered to represent gravel waves formed by very strong currents.

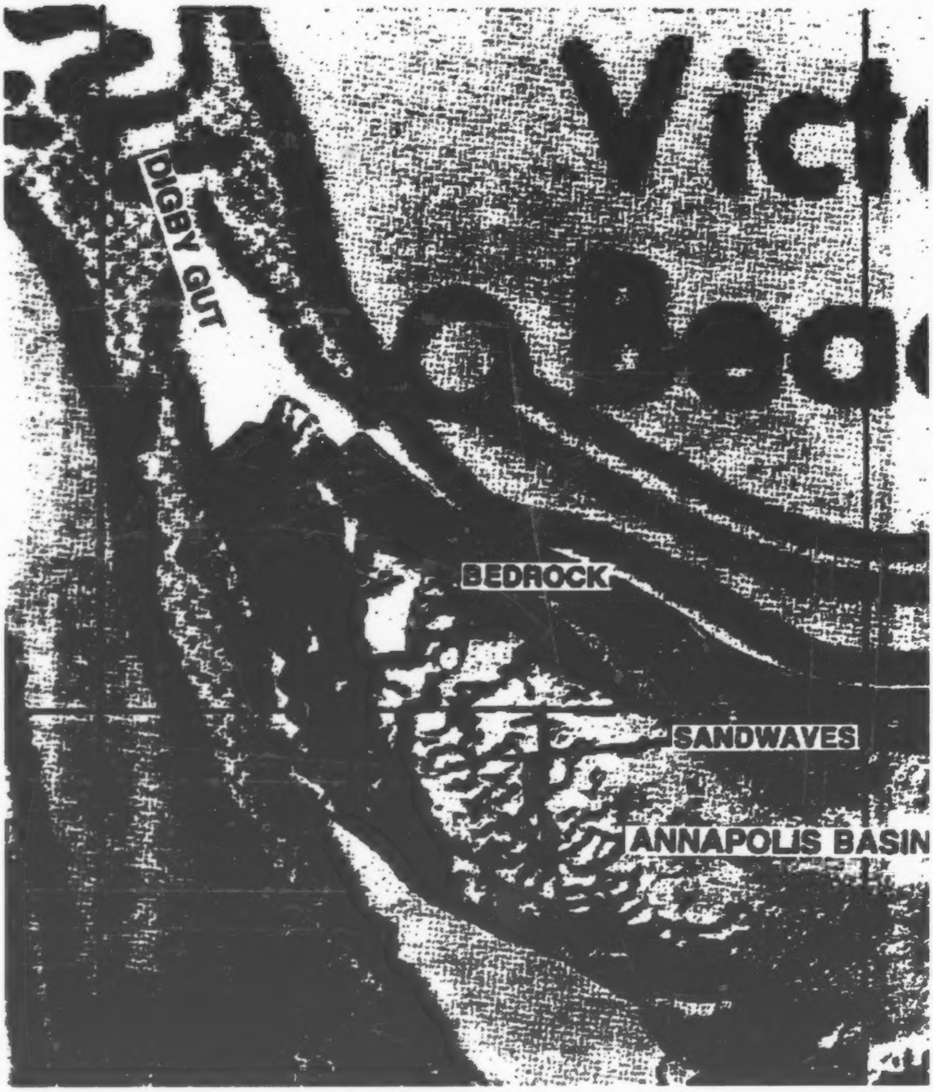
Vict
Bea
DIGBY GUT
BEDROCK
SANDWAVES
ANNAPOLIS BASIN

Figure 5.5-4. Multibeam imagery showing gravel waves off the southern end of Digby Gut, where charted tidal current speeds are 1.5 m/s (3 knot), with flood currents dominant.

5.5.3. *Utility Grid Interconnection*

Interconnection to the NSPI grid is shown in Figure 5.5-7 for 12 kV and Figure 5.5-8 for 69 kV.

Digby Gut - Victoria Beach Feed – 12kV-302
Suitable for <200KW

Figure 5.5-5. Distance from site to closest 12 kV connection

For the 69 kV connection Digby Gut – 77V-303 12KV circuit 7 km upgrade to 3-phase.
Suitable for <1 Mw

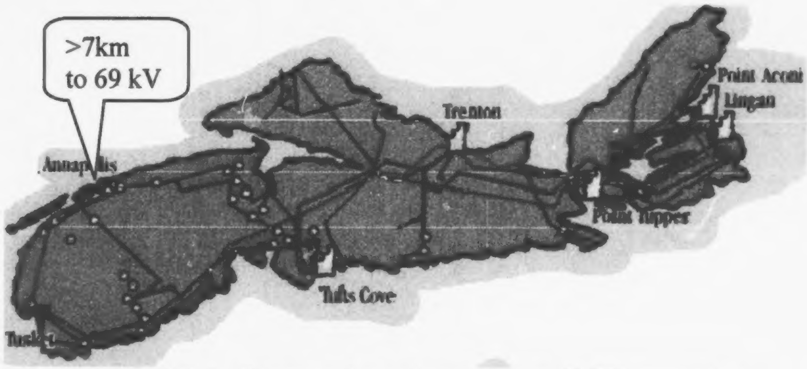
>7km
to 69 kV
Point Aconi
Lingan
Trenton
Annapolis
Point Tupper
Tufts Cove

Figure 5.5-6. Distance from site to closest 69 kV connection

5.5.4. Maritime Support Infrastructure

Appendix B provides information about marine support services and fabricators in Nova Scotia. As detailed there, a wide variety of shipyards and offshore marine contractors exists is the Halifax-Dartmouth area, well suited for fabrication and assembly of TISEC devices.

The main public wharf in Digby has a length of 95m, allowing a maximum alongside draft of 12.9 m at high tide. Ferry traffic is loaded and unloaded daily at the main wharf, and numerous fishing and recreational vessels tie up to its inner spurs. Given the heavy use of this wharf for other purposes, it would be difficult to establish a shoreside service facility here.

For shoreside support services (inspection, maintenance, and repair of operating devices), the nearest cities with an extensive maritime infrastructure are Yarmouth and Saint John, New Brunswick. Yarmouth is slightly farther away from Digby Gut than Saint John, and any service vessel operating out of Yarmouth, or any tow back into Yarmouth, would be more exposed to severe weather from the Gulf of Maine.

Therefore, Saint John, New Brunswick is recommended as the shoreside support center for any TISEC projects in Digby Gut.

5.5.5. Environmental Considerations

Digby Gut is the home of a large fishing fleet that regularly uses the passage, and the terminal for the ferry between Digby and Saint John, New Brunswick, is located just inside the gut on its western shore. South of the ferry terminal, aquaculture sites are located in the western part of the passage where it joins Annapolis Basin. Lobster gear is regularly positioned in the gut adjacent to the channel during lobster season. Active environmental associations also exist in the region.

Therefore, siting of any TISEC projects here will have to be done very carefully and in close consultation with the many users of this busy channel, as well as local environmental activists. Such a consultative project implementation process will undoubtedly pave the way for wider acceptance of this technology across Atlantic Canada.

5.5.6. Unique Opportunities

It is worth noting that the tidal in-stream potential installed capacity here, withdrawing only 15% of the resource base, is 20 MW, which equals the generating capacity of the impoundment tidal power plant at Annapolis Royal. It is anticipated that the environmental impacts of an in-stream project of this magnitude will be much less than an impoundment plant. It also represents an opportunity to demonstrate the compatibility of this technology with many other diverse uses.

This site thus represents an excellent public visibility opportunity, since it would enable visitors to this region to compare two different tidal power technologies within a relatively short driving distance. It also would be highly visible to travelers on the Saint John – Digby ferry route.

5.6 Petit Passage

Petit Passage is the name for the channel that separates Long Island from Digby Neck at the entrance of the Bay of Fundy. It is approximately 10 km northeast of Grand Passage and similar in orientation. It connects the Bay of Fundy with the inner area of St. Marys Bay to the south (Figure 5.6-1). Petit Passage is 7.4 km in length and 0.54 in width, narrower than Grand Passage to the south.

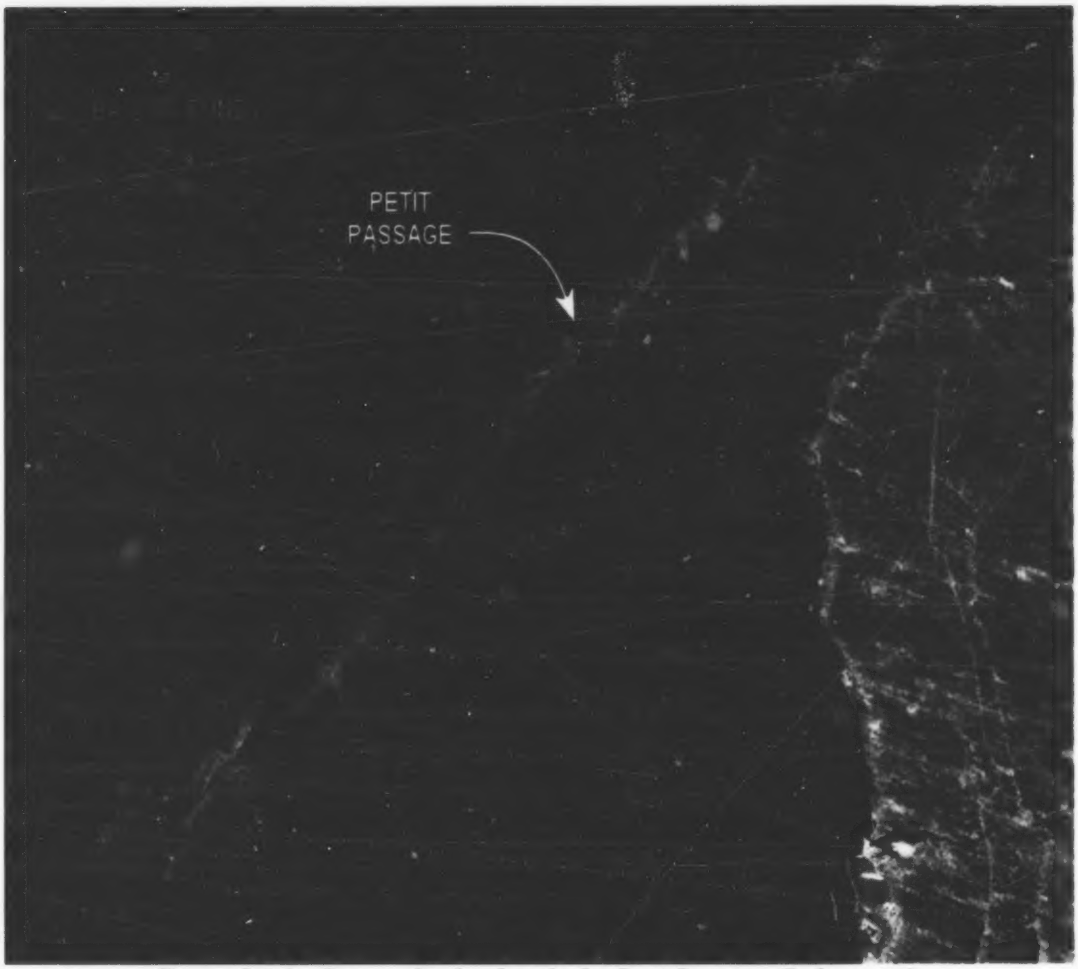

Figure 5.6-1. Geographic landmarks for Petit Passage (Reference 6).

5.6.1. Tidal In-Stream Energy Resource

Potential project transects in Petit Passage are shown in Figure 5.6-2, below. Also shown are nearby locations where measured current data exist, archived in the Ocean Data Inventory (ODI) maintained by the Department of Fisheries and Oceans Canada.

ODI Series Designation	Latitude (deg N)	Longitude (deg W)	Depth (m)	Series Start Date & End Date	Series Duration
MCM_66999_11_1_300	44.38	66.21	18	26 May – 25 Jun 66	30 days
MCM_66999_2_4_300	44.405	66.21	15	01 Jun – 23 Jun 66	22 days

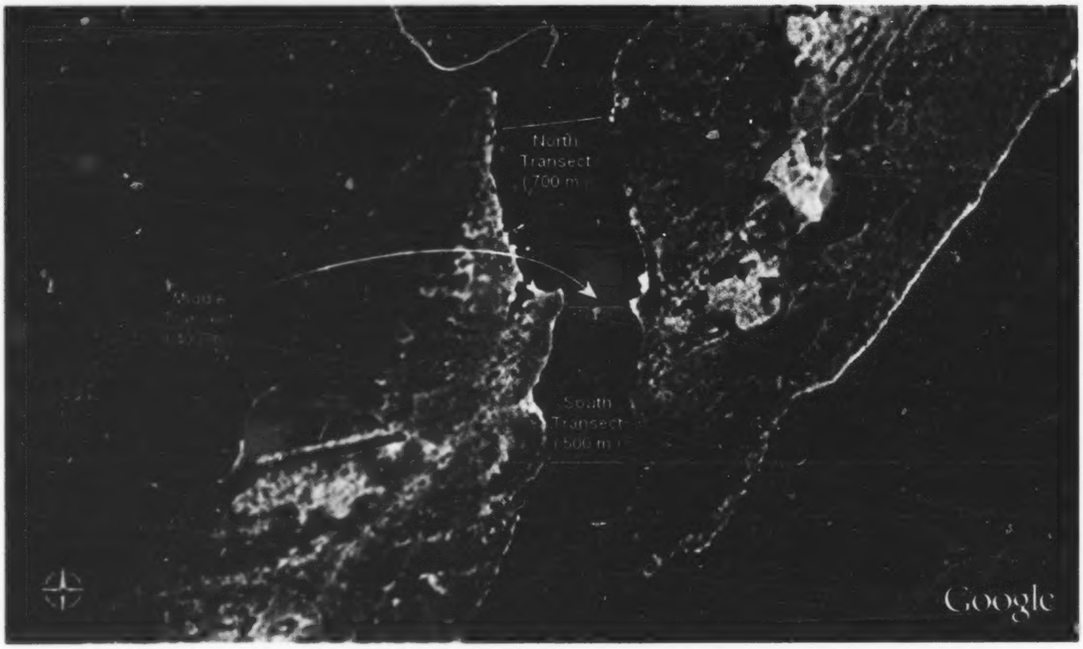

Figure 5.6-2. Aerial photograph from an altitude of approximately 6 km, showing the numerically modeled transects in Petit Passage (Reference 6).

5.6.1. Tidal In-Stream Energy Resource

Potential project transects in Petit Passage are shown in Figure 5.6-2, below. Also shown are nearby locations where measured current data exist, archived in the Ocean Data Inventory (ODI) maintained by the Department of Fisheries and Oceans Canada.

ODI Series Designation	Latitude (deg N)	Longitude (deg W)	Depth (m)	Series Start Date & End Date	Series Duration
MCM_66999_11_1_300	44.38	66.21	18	26 May – 25 Jun 66	30 days
MCM_66999_2_4_300	44.405	66.21	15	01 Jun – 23 Jun 66	22 days

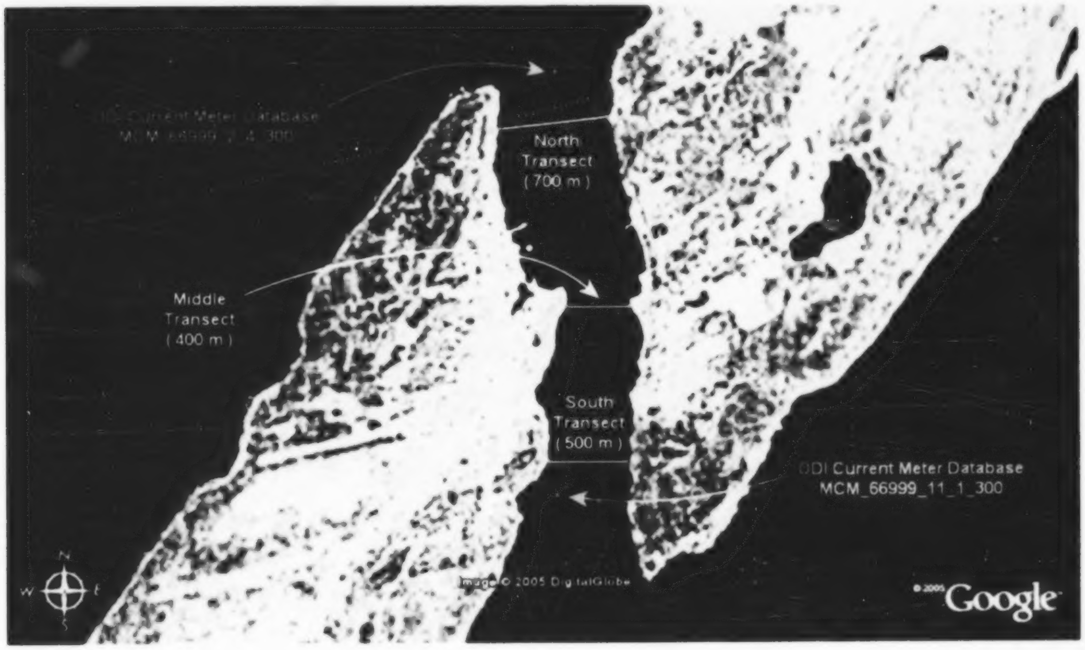
ODI Current Meter Database
MCM_66999_2_4_300
North
Transect
(700 m)
Middle
Transect
(400 m)
South
Transect
(500 m)
ODI Current Meter Database
MCM_66999_11_1_300
N
W
E
S
Image © 2005 DigitalGlobe
© 2005 Google

Figure 5.6-2. Aerial photograph from an altitude of approximately 6 km, showing the numerically modeled transects in Petit Passage (Reference 6).

CHS chart #4118 indicates that peak current speeds of 7 knots can be expected in Petit Passage (Figure 5.6-3). The calculation below uses this value as the average peak current velocity at the middle transect (Figure 5.6-2), where the channel is most narrow, which corresponds to a peak tidal stream power density of 24 kW/m^2 at the surface.

Assuming that the time series profile of tidal stream velocity can be approximated by a sinusoidal curve, then the time-averaged velocity over one tidal period would be 63.7% of the peak velocity. Moreover, the mean value of the velocity-cubed over one tidal period would be 42.4% of the peak velocity cubed. Since tidal in-stream power density is proportional to velocity cubed, then the mean power density averaged over an entire tidal period would be 42.4% of 24 kW /m^2, which is 10 kW/m^2.

Since this is based on the surface velocity, it needs to be adjusted to estimate the depth-averaged tidal stream power density. Assuming that a 1/10-power law approximates the decrease in velocity from the surface to the bottom of the channel, then the depth-averaged value of velocity cubed would be 76.9% of its surface value. This yields a depth-averaged tidal stream power density of 18 kW/m^2 for peak ebb and flood currents, and 7.7 kW/m^2 averaged over time.

The cross-sectional area of the middle transect is estimated from the CHS chart to be 8,000 m^2, giving a total resource base of 61,600 kW. Withdrawing 15% of this power yields an extractable resource of 9,200 kW. Assuming a "water to wire" conversion efficiency of 80% and a project capacity factor of 40%, then the maximum tidal in-stream capacity that could be installed at this site is 18,400 kW.

Note that this is significantly higher than the potential installed capacities in the much wider transects at Cumberland Basin and Cobequid Bay. Although Petit Passage has a much smaller cross-sectional area, the current speeds here are much higher (7 knots vs. 3.5 and 4.5 knots), which translates to a much higher energy flux due to the velocity-cubed factor.

5.6.2. Seafloor Bathymetry and Geology

A hydrographic chart of the Cumberland Basin entrance is given below.

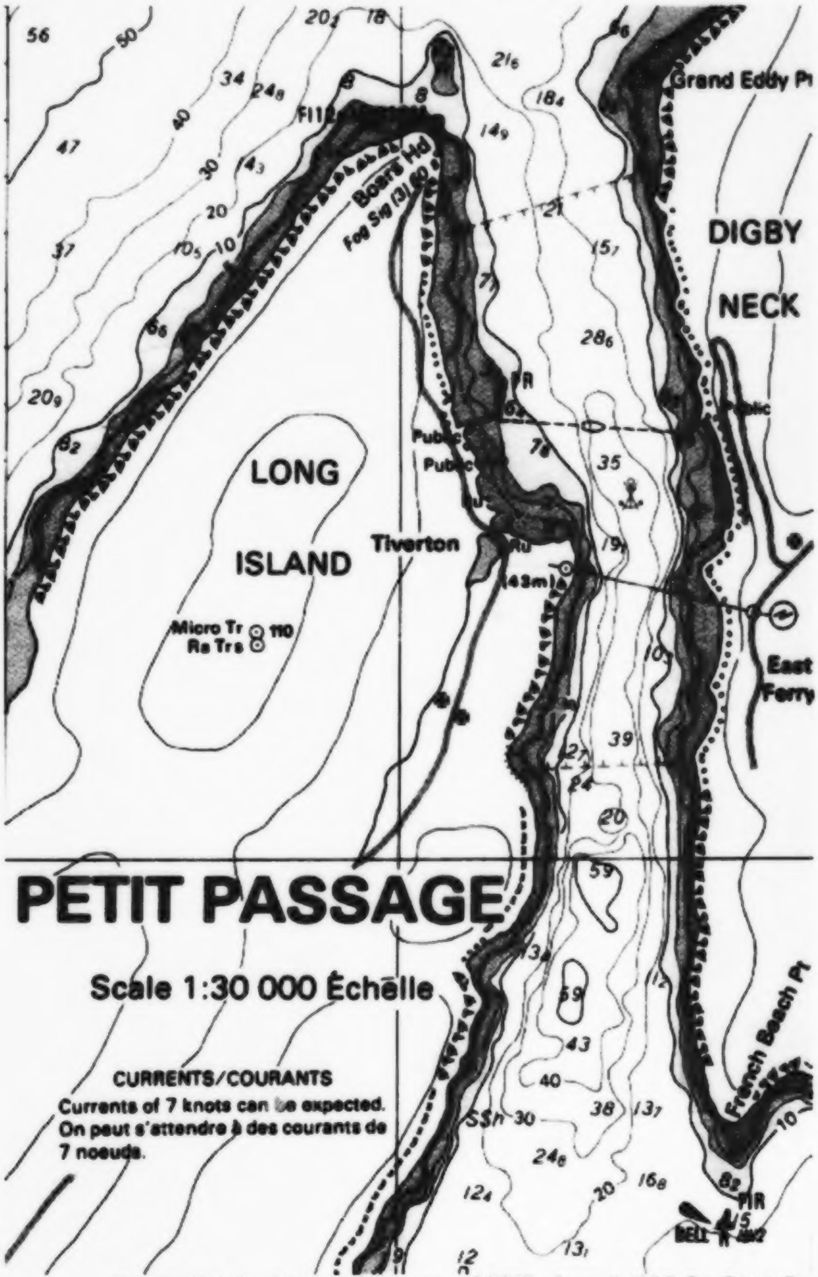
Grand Eddy Pt
DIGBY
NECK
Boars Hd
Fog Sig
LONG
ISLAND
Tiverton
Public
Micro Tr
Ra Trs
110
East
Ferry
PETIT PASSAGE
Scale 1:30 000 Échelle
CURRENTS/COURANTS
Currents of 7 knots can be expected.
On peut s'attendre à des courants de 7 noeuds.
French Beach Pt
BELL

Figure 5.6-3. Scanned section of CHS chart #4118 for Petit Passage. Depths are in meters (1 m = 3.3 ft).

Petit Passage is defined by the 20 m contour. Two deep depressions occur in the southern part of the channel with spot depths of 59 m surrounded by circular isolated 50 m contours. The base of the channel narrows at the entrance in the north with an 18 m shallow projection from the east. A 20 m shallow area occurs to the north of the 59 m deep depression in the southern

Similar to Digby Gut and Grand Passage, the origin of the Petit Passage is interpreted to have resulted from the presence of a north-south fault with subsequent movement. Long Island is offset by 00.9 km to the north as a result of the strike slip movement on the fault. The fault does not appear to continue to the north and there is no deformation in the overlying Triassic/Jurassic sediments further offshore on the seismic reflection profiles. This suggests that the fault is very old and has not been active since Jurassic time.

Sediment samples have not been collected in Petit Passage, but if sediment does occur, it is likely to be gravel-armoured glacial till. Boulders are expected to be common and are found along the Digby Neck nearshore area. The history of relative sea level change throughout the Fundy region clearly defines both a high stand of 40 m above and a low stand of 60 m below existing sea level for Long Island and adjacent areas following the last glaciation of the region 14,000 to 22,000 years ago. This changing relative sea level eroded most preexisting glacial sediments leaving behind thin, well-sorted gravels and sands.

5.6.3. *Utility Grid Interconnection*

Interconnection to the NSPI grid is shown in Figure 5.6-7 for 25 kV and Figure 5.6-8 for 69 kV.

Approximately 1 km to 25 kV connection
Tiverton (Petit Passage) – 77V-401
<2MW direct
<1MW induction

Figure 5.6.4. Distance to closest 25 kV connection

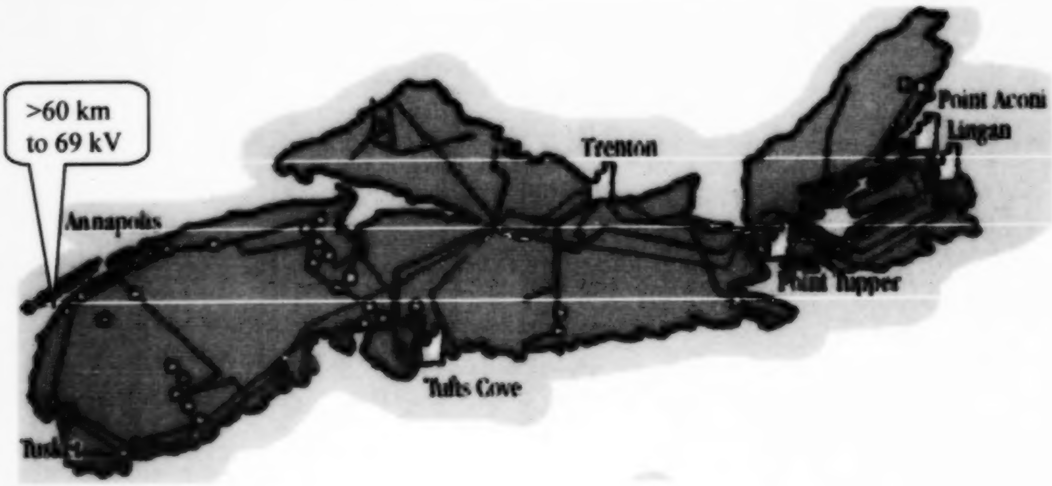

Figure 5.6.5. Distance to closest 69 kV connection

5.6.4. Maritime Support Infrastructure

Appendix B provides information about marine support services and fabricators in Nova Scotia. As detailed there, a wide variety of shipyards and offshore marine contractors exists is the Halifax-Dartmouth area, well suited for fabrication and assembly of TISEC devices.

For shoreside support services (inspection, maintenance, and repair of operating devices), the nearest city with an extensive maritime infrastructure is Saint John, New Brunswick. Even though Yarmouth is closer, any service vessel operating out of Yarmouth, or any tow back into Yarmouth would be more exposed to severe weather from the Gulf of Maine.

Therefore, Saint John is recommended as the shoreside support center for any TISEC projects in Petit Passage, although Yarmouth might also be considered. As explained in Section 5.6.4, Digby is not well suited to be a local support center.

5.6.5. Environmental Considerations

A small automobile ferry regularly transits the passage. The central part of the passage is a no anchorage zone. The communities of East Ferry and Tiverton occur on the shores of the passage and the main industries are tourism and fishing including whale watching. Active environmental associations exist in the region.

5.6.6. Unique Opportunities

There is an overhead power cable across the passage that might be useable for interconnection

5.7 Grand Passage

Grand Passage is the name for the channel that separates Brier Island from Long Island at the entrance of the Bay of Fundy. It connects the Bay of Fundy with the outer area of St. Marys Bay in the south (Figure 5.7-1). The overall orientation of the channel is north-south, but the channel takes an eastward jog at approximately 75% of the distance from the north and is followed by another rapid change of direction to the south giving the overall channel an "S" shape. Where the channel takes the rapid turn east, it narrows between Passage Shoal and Peter Island, a small island in the south of the channel.

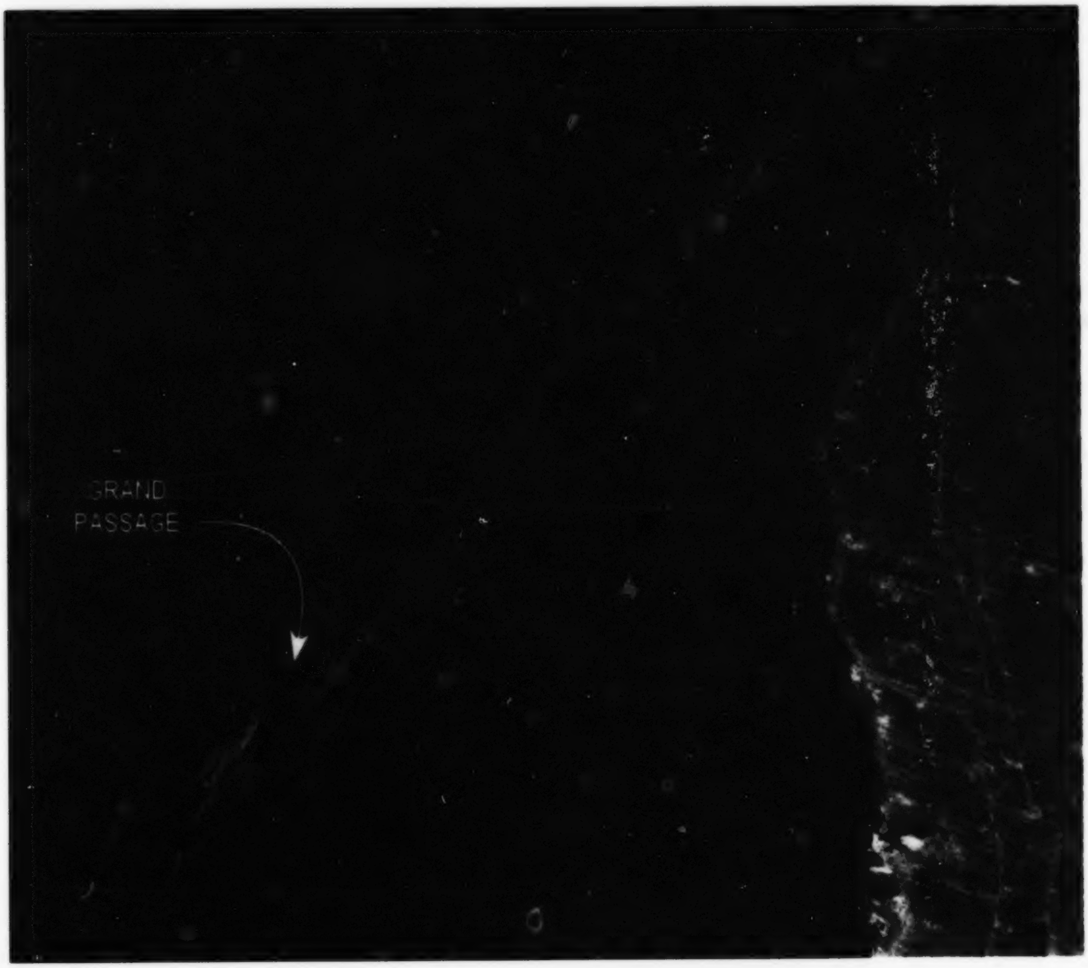

Figure 5.7-1. Geographic landmarks for Grand Passage (Reference 6).

5.7.1. Tidal In-Stream Energy Resource

Potential project transects in Grand Passage are shown in Figure 5.7-2. below. There are no measured current data for this site archived in the Ocean Data Inventory (ODI) maintained by the Department of Fisheries and Oceans Canada.

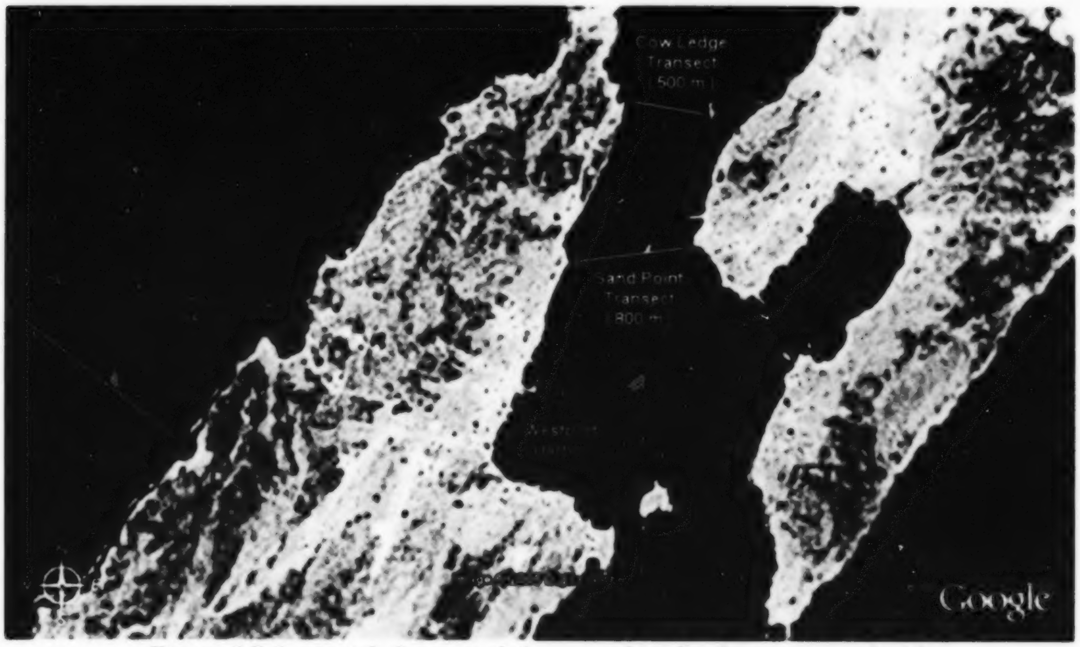
Cow Ledge
Transect
(500 m)
Sand Point
Transect
(800 m)
Google

Figure 5.7-2. Aerial photograph from an altitude of approximately 6 km, showing the numerically modeled transects in Grand Passage (Reference 6).

5.7.1. Tidal In-Stream Energy Resource

Potential project transects in Grand Passage are shown in Figure 5.7-2, below. There are no measured current data for this site archived in the Ocean Data Inventory (ODI) maintained by the Department of Fisheries and Oceans Canada.

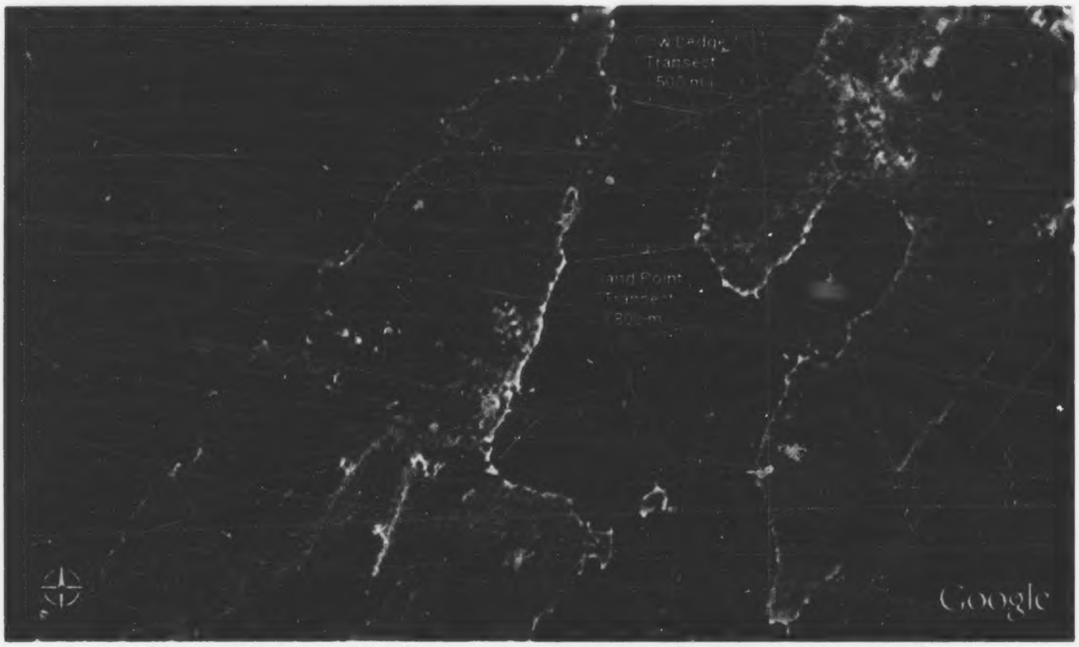

Figure 5.7-2. Aerial photograph from an altitude of approximately 6 km, showing the numerically modeled transects in Grand Passage (Reference 6).

CHS chart #4118 indicates that peak current speeds of 6 knots can be expected in Grand Passage (Figure 5.7-3). The calculation below uses this value as the average peak current velocity at the Cow Ledge transect (Figure 5.7-2), where the channel is most narrow, which corresponds to a peak tidal stream power density of 15 kW/m^2.

Assuming that the time series profile of tidal stream velocity can be approximated by a sinusoidal curve, then the time-averaged velocity over one tidal period would be 63.7% of the peak velocity. Moreover, the mean value of the velocity-cubed over one tidal period would be 42.4% of the peak velocity cubed. Since tidal in-stream power density is proportional to velocity cubed, then the mean power density averaged over an entire tidal period would be 42.4% of 15 kW /m^2, which is 6.4 kW/m^2.

Since this is based on the surface velocity, it needs to be adjusted to estimate the depth-averaged tidal stream power density. Assuming that a 1/10-power law approximates the decrease in velocity from the surface to the bottom of the channel, then the depth-averaged value of velocity cubed would be 76.9% of its surface value. This yields a depth-averaged tidal stream power density of 11.5 kW/m^2 for peak ebb and flood currents, and 4.9 kW/m^2 averaged over time.

The cross-sectional area of the middle transect is roughly estimated from the CHS chart to be 9,000 m^2, giving a total resource base of 44,100 kW. Withdrawing 15% of this power yields an extractable resource of 6,600 kW. Assuming a "water to wire" conversion efficiency of 80% and a project capacity factor of 40%, then the maximum tidal in-stream capacity that could be installed at this site is 13,200 kW.

5.7.2. Seafloor Bathymetry and Geology

A hydrographic chart of Grand Passage is given below.

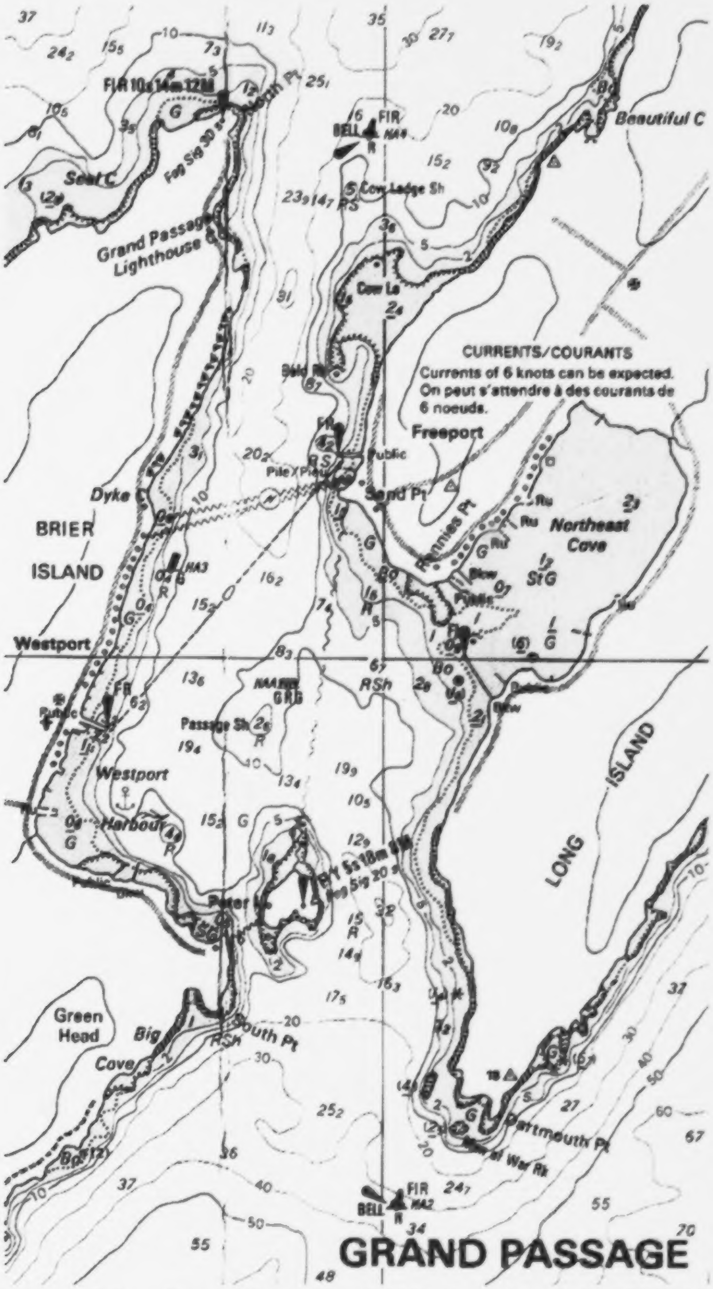
Seal C
Grand Passage Lighthouse
Cow Ledge Sh
Cow Le
Beautiful C
CURRENTS/COURANTS
Currents of 6 knots can be expected.
On peut s'attendre à des courants de 6 noeuds.
Freeport
Dyke
Sand Pt
BRIER
ISLAND
Northeast
Cove
Westport
Passage Sh
Westport
Harbour
LONG
ISLAND
Peter Id
Green
Head
Big
Cove
South Pt
Dartmouth Pt
Man of War Rk
GRAND PASSAGE

Figure 5.7-2. . Scanned section of CHS chart #4118 for Grand Passage. Depths are in meters (1 m = 3.3 ft).

5.7.2. Seafloor Bathymetry and Geology

A hydrographic chart of Grand Passage is given below.

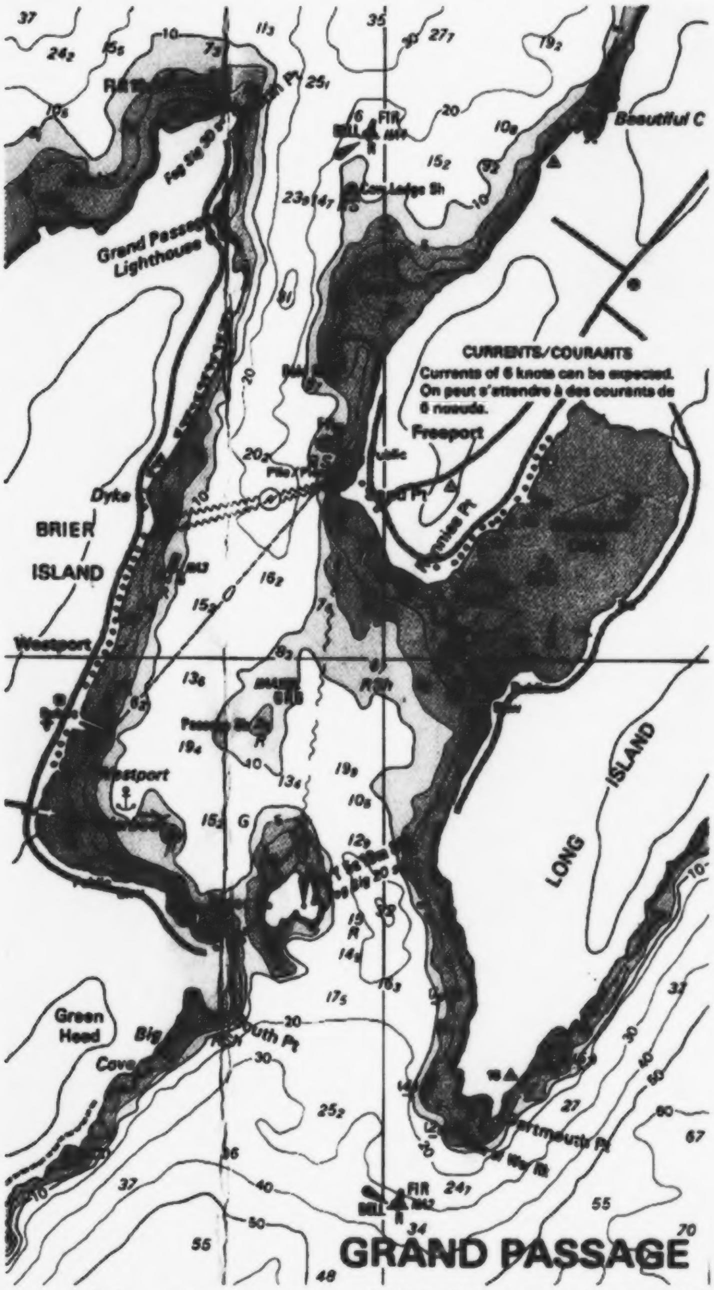
Grand Passage Lighthouse
CURRENTS/COURANTS
Currents of 6 knots can be expected.
On peut s'attendre à des courants de
6 noeuds.
Freeport
Beautiful C
Dyke
BRIER
ISLAND
Westport
LONG
ISLAND
Green
Head
Big
Cove
GRAND PASSAGE

Figure 5.7-2. . Scanned section of CHS chart #4118 for Grand Passage.
Depths are in meters (1 m = 3.3 ft).

Grand Passage is defined by the 10 and 20 m contours and some of the shallower spot depths are 15, 13, 19, 10 and 12 m. Two deeper depressions occur in the channel, one in the north at 31 m, and one in the south at 32 m.

North Mountain Formation basalt occurs on both Brier and Long Islands on either side of the passage and the basalt is interpreted to be continuous across the passage. It is not known if surficial sediments occur in the passage but because of the strong currents no muds are expected. If they exist the sediments would be till and covered in lag gravels with boulders.

The origin of Grand Passage is interpreted to have resulted from the presence of a north-south fault with subsequent movement. Brier Island is offset by 1.1 km to the north as a result of strike slip movement of the island. That fault joins with another southwest – northeast fault more or less parallel to the north coast of Brier Island. These faults do not appear to continue to the north and there is no deformation seen on the seismic reflection profiles in the overlying Triassic/Jurassic sediments further offshore. This suggests that the faults are very old and have not been active since Jurassic time.

5.7.3. Utility Grid Interconnection

Interconnection to the NSPI grid is shown in Figure 5.7-7 for 12 kV and Figure 5.7-8 for 69 kV.

Freeport (Grand Passage) –
12KV
500KW direct
300kw induction

Figure 5.7-4 Distance to closest 12kV connection

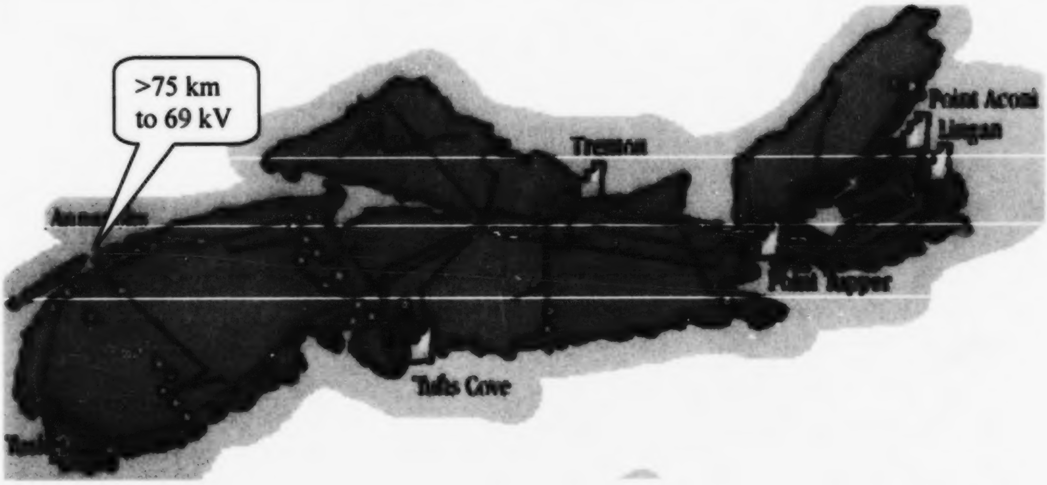

Figure 5.7-5 Distance to closest 69kV connection

5.7.4. Maritime Support Infrastructure

Appendix B provides information about marine support services and fabricators in Nova Scotia. As detailed there, a wide variety of shipyards and offshore marine contractors exists is the Halifax-Dartmouth area, well suited for fabrication and assembly of TISEC devices.

For shoreside support services (inspection, maintenance, and repair of operating devices), the nearest city with an extensive maritime infrastructure is Saint John, New Brunswick. Even though Yarmouth, Nova Scotia is closer, any service vessel operating out of Yarmouth, or any tow back into Yarmouth would be more exposed to severe weather from the Gulf of Maine.

Therefore, Saint John is recommended as the shoreside support center for any TISEC projects in Grand Passage, although Yarmouth might also be considered. As explained in Section 5.6.4, Digby is not well suited to be a local support center.

5.7.5. Environmental Considerations

A small automobile ferry regularly transits the passage. The communities of Freeport and Westport occur on the shores of the passage and the main industries are tourism and fishing for ground fish, lobster and herring. Whale watching is a growing local industry.

There have been proposals to define benthic and pelagic priority areas that cover Brier Island and adjacent areas put forth by the Marine Conservation Biology Institute. Active environmental associations exist in the region. Peters Island in the passage is a designated bird sanctuary.

5.7.6. Unique Opportunities

There are several cables that lie on the seabed between the islands. Easement corridors may be useable for a tidal plant power cable.

5.8 Great Bras d'Or Channel

The Bras d'Or Lakes are a series of low-salinity bodies of water in central Cape Breton Island, Nova Scotia surrounded by land (Figure 5.8-1). Great Bras d'Or Channel is one of three entrances to the Bras d'Or Lakes, connecting them to the Atlantic Ocean. It is the longest and narrowest of the three and is approximately 31.5 km long and averages 1.4 km in width.

GREAT BRAS D'OR CHANNEL

Figure 5.8-1. Geographic landmarks for Great Bras d'Or Channel (Reference 6).

5.8.1. Tidal In-Stream Energy Resource

The northern entrance to the Great Bras d'Or Channel is one of three CHS tidal current prediction stations in Atlantic Canada (Reference 4). The geographic coordinates of this station are latitude 46°18' N, longitude 60°25' W, which are mapped in Figure 5.8-2, below. Note that the tidal current station is not at the narrowest part of the channel entrance.

Figure 5.8-2. Location of tidal current prediction station at the northern entrance of Great Bras d'Or Channel.

According to the 2001 *Sailing Directions, Gulf of Maine and Bay of Fundy* (Reference 5):

> The normal rate of the current is 4 to 5 knots. In the spring after a NE gale, the level of the Bras d'Or Lakes may be raised considerably, increasing the rate to 6 knots and forming rips and eddies, especially off Carey Point.
>
> The tidal currents do not set straight through the channel and generally are the reverse of the tide. The outgoing current sets to the N after passing Carey Point and generally flows on the rising tide. The incoming current sets towards the E side of the channel and flows on the falling tide.

5.8 Great Bras d'Or Channel

The Bras d'Or Lakes are a series of low-salinity bodies of water in central Cape Breton Island. Nova Scotia surrounded by land (Figure 5.8-1). Great Bras d'Or Channel is one of three entrances to the Bras d'Or Lakes. connecting them to the Atlantic Ocean. It is the longest and narrowest of the three and is approximately 31.5 km long and averages 1.4 km in width.

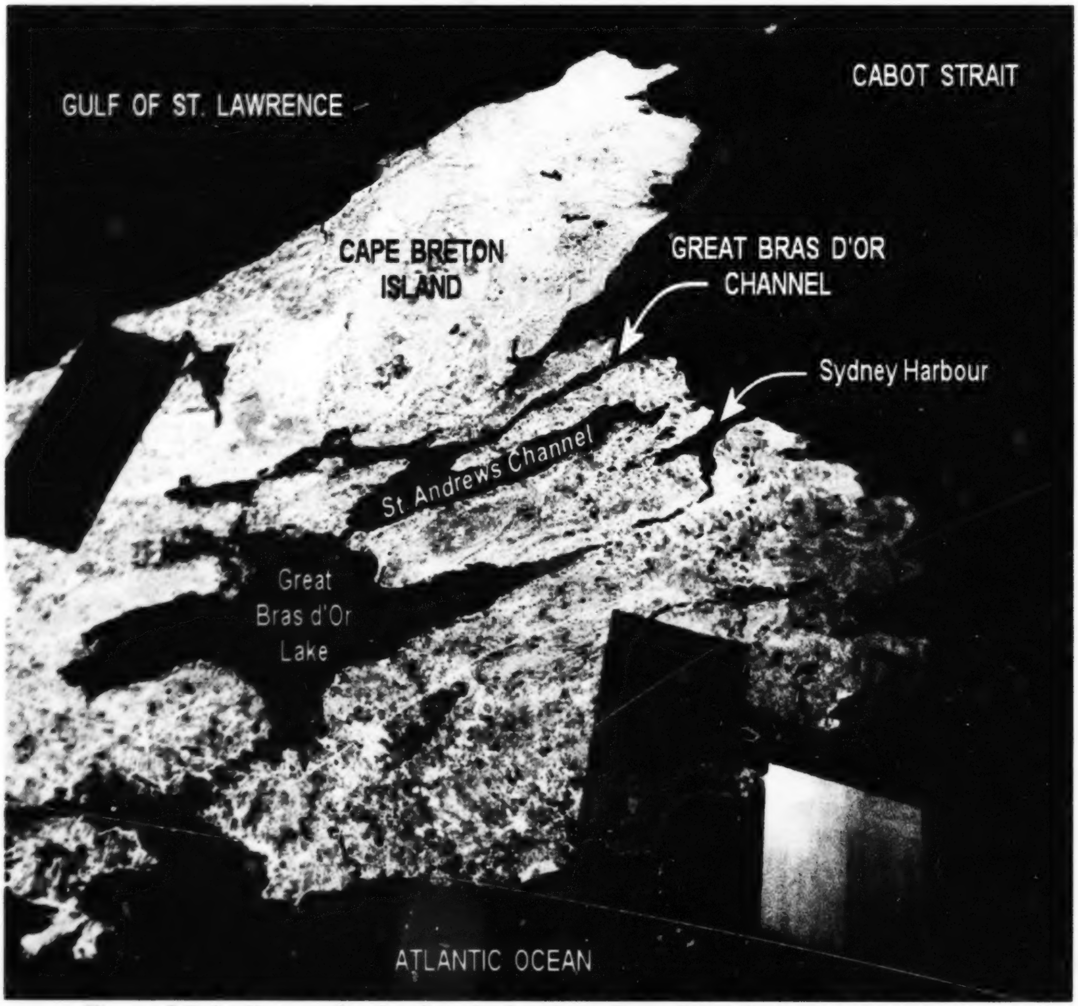
GULF OF ST. LAWRENCE
CABOT STRAIT
CAPE BRETON ISLAND
GREAT BRAS D'OR CHANNEL
Sydney Harbour
St Andrews Channel
Great Bras d'Or Lake
ATLANTIC OCEAN

Figure 5.8-1 Geographic landmarks for Great Bras d'Or Channel (Reference 6).

5.8.1. Tidal In-Stream Energy Resource

The northern entrance to the Great Bras d'Or Channel is one of three CHS tidal current prediction stations in Atlantic Canada (Reference 4). The geographic coordinates of this station are latitude 46°18' N. longitude 60°25' W. which are mapped in Figure 5.8-2. below. Note that the tidal current station is not at the narrowest part of the channel entrance.

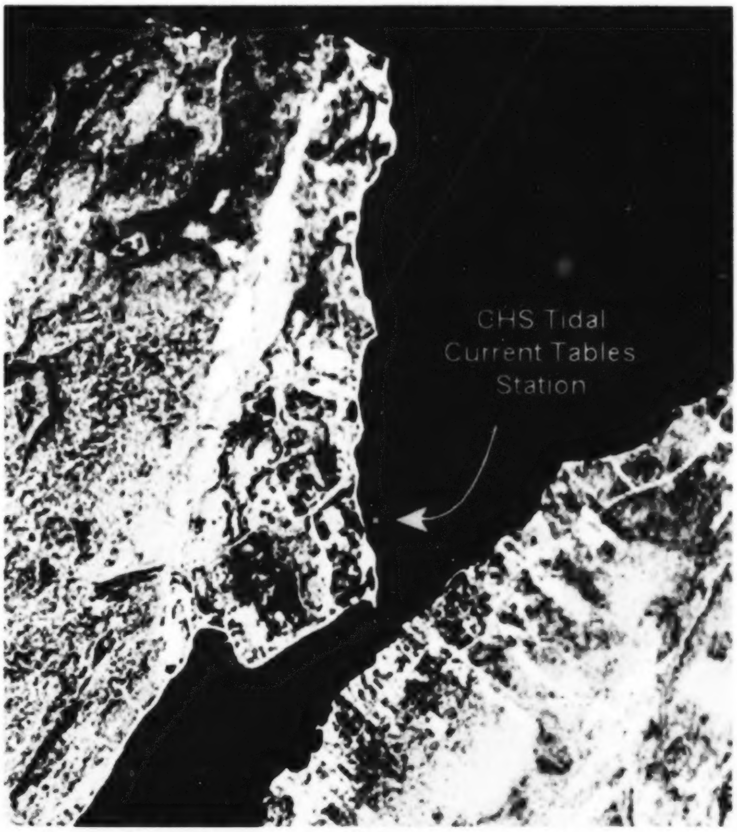

Figure 5.8-2. Location of tidal current prediction station at the northern entrance of Great Bras d'Or Channel.

According to the 2001 *Sailing Directions, Gulf of Maine and Bay of Fundy* (Reference 5):

> The normal rate of the current is 4 to 5 knots. In the spring after a NE gale, the level of the Bras d'Or Lakes may be raised considerably, increasing the rate to 6 knots and forming rips and eddies, especially off Carey Point.
>
> The tidal currents do not set straight through the channel and generally are the reverse of the tide. The outgoing current sets to the N after passing Carey Point and generally flows on the rising tide. The incoming current sets towards the E side of the channel and flows on the falling tide.

The calculation below uses 4.5 knots (2.3 m/sec), as the average peak surface current velocity, which corresponds to a peak tidal stream power density of 6.4 kW/m^2 at the surface.

Assuming that the time series profile of tidal stream velocity can be approximated by a sinusoidal curve, then the time-averaged velocity over one tidal period would be 63.7% of the peak velocity. Moreover, the mean value of the velocity-cubed over one tidal period would be 42.4% of the peak velocity cubed. Since tidal in-stream power density is proportional to velocity cubed, then the mean power density averaged over an entire tidal period would be 42.4% of 6.4 kW/m^2, which is 2.7 kW/m^2.

Since this is based on the surface velocity, it needs to be adjusted to estimate the depth-averaged tidal stream power density. Assuming that a 1/10-power law approximates the decrease in velocity from the surface to the bottom of the channel, then the depth-averaged value of velocity cubed would be 76.9% of its surface value. This yields a depth-averaged tidal stream power density of 4.9 kW/m^2 for peak ebb and flood currents, and 2.1 kW/m^2 averaged over time.

The Great Bras d'Or Channel opens into the Atlantic to the northeast with a sill depth of 9 m and a minimum width of 500 m, giving it a cross-sectional area of 4,500 m^2 and a total resource base of 9,450 kW. Withdrawing 15% of this power yields an extractable resource of 1,400 kW. Assuming a "water to wire" conversion efficiency of 80% and a project capacity factor of 40%, then the maximum tidal in-stream capacity that could be installed at this site is 2,800 kW.

5.8.2. Seafloor Bathymetry and Geology

Water depths range to 20 m in the northern part of the channel and are up to 100 m in the deeper southern area. The minimum depth in the channel is 8 m.

The bedrock geology of Great Bras d'Or Channel can be assessed from an understanding of the rocks on both sides of this narrow channel (Figure 3.8-3). The eastern shore is Carboniferous sandstone, siltstone and shale. To the west on the mainland across the channel, the bedrock is largely resistant crystalline (volcanic of metamorphic) rocks. Some Windsor Group shale's and evaporates occur on the southwestern side of the channel. The contact between the Carboniferous sediments and the older crystalline rocks lies largely beneath the channel and is likely fault controlled in places.

Rifting at the end of the Devonian period over 360 million years ago formed a series of fault bounded basins between highlands of crystalline rocks. Flooding of these basins deposited a thick sequence of muds and evaporates including gypsum, anhydrite and salt. These Windsor aged rocks underlie most of the Bras d'Or Lakes. Younger Carboniferous sandstones were subsequently deposited over these rocks. This was followed by regional uplift and river erosion, particularly during the Tertiary, which developed the lowlands of the region. The deep water depressions of the Bras d'Or Lakes including Great Bras d'Or Channel may owe part of their origin to dissolution of the evaporates as sinkholes and karst topography has been found on the lake bottom.

Figure 3.8-4 is the multibeam bathymetric, colour depth-coded, shaded-relief map of both Great Bras D'Or Channel and St. Andrews Channel to the southeast. The northern part of the channel is very shallow and a field of large bedforms occurs just inside the sill where it meets the Atlantic. The bedforms may be gravel waves formed by strong currents. The seismic section from this area shows a thick progradational sequence of gas-charged sediments. These are interpreted as a flood tidal delta deposit.

The seabed becomes rougher with a variety of ridged topography and a central deeper channel near the area of the bridge crossing. South of the bridge crossing the channel is much deeper and a series of ridges are normal to the channel. These may represent either bedforms or bedrock ridges. John Shaw (personal communication, 2005) suggests that bedrock does not crop out at the seabed throughout most of the Channel area. The floor is covered by sediments of varying thickness, with gravel at the lakebed.

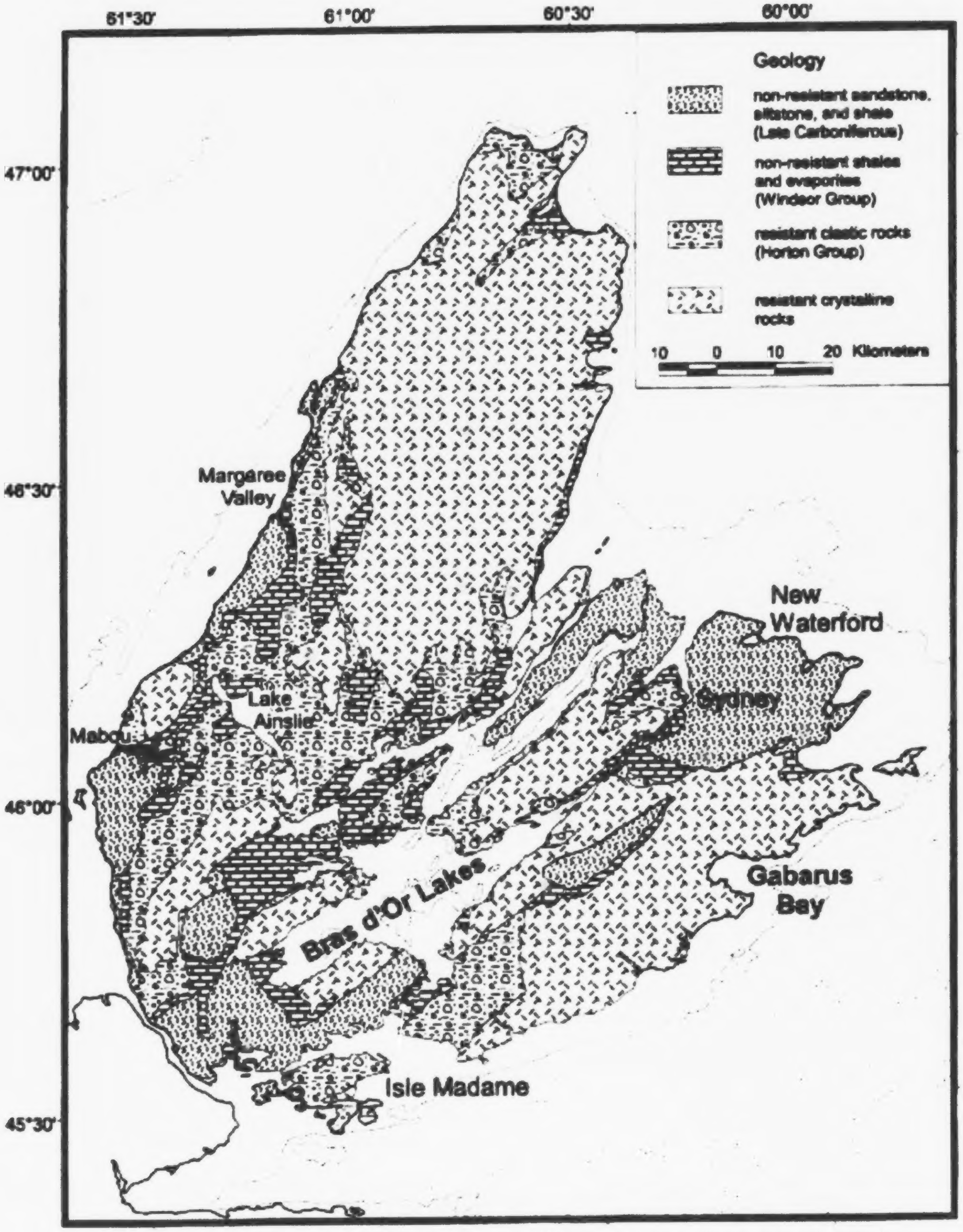
61°30'
61°00'
60°30'
60°00'
47°00'
46°30'
46°00'
45°30'
Geology
non-resistant sandstone, siltstone, and shale (Late Carboniferous)
non-resistant shales and evaporites (Windsor Group)
resistant clastic rocks (Horton Group)
resistant crystalline rocks
10 0 10 20 Kilometers
Margaree Valley
Lake Ainslie
Mabou
New Waterford
Sydney
Gabarus Bay
Bras d'Or Lakes
Isle Madame

Figure 5.8-3. Regional bedrock geology adjacent to Great Bras d'Or Channel.

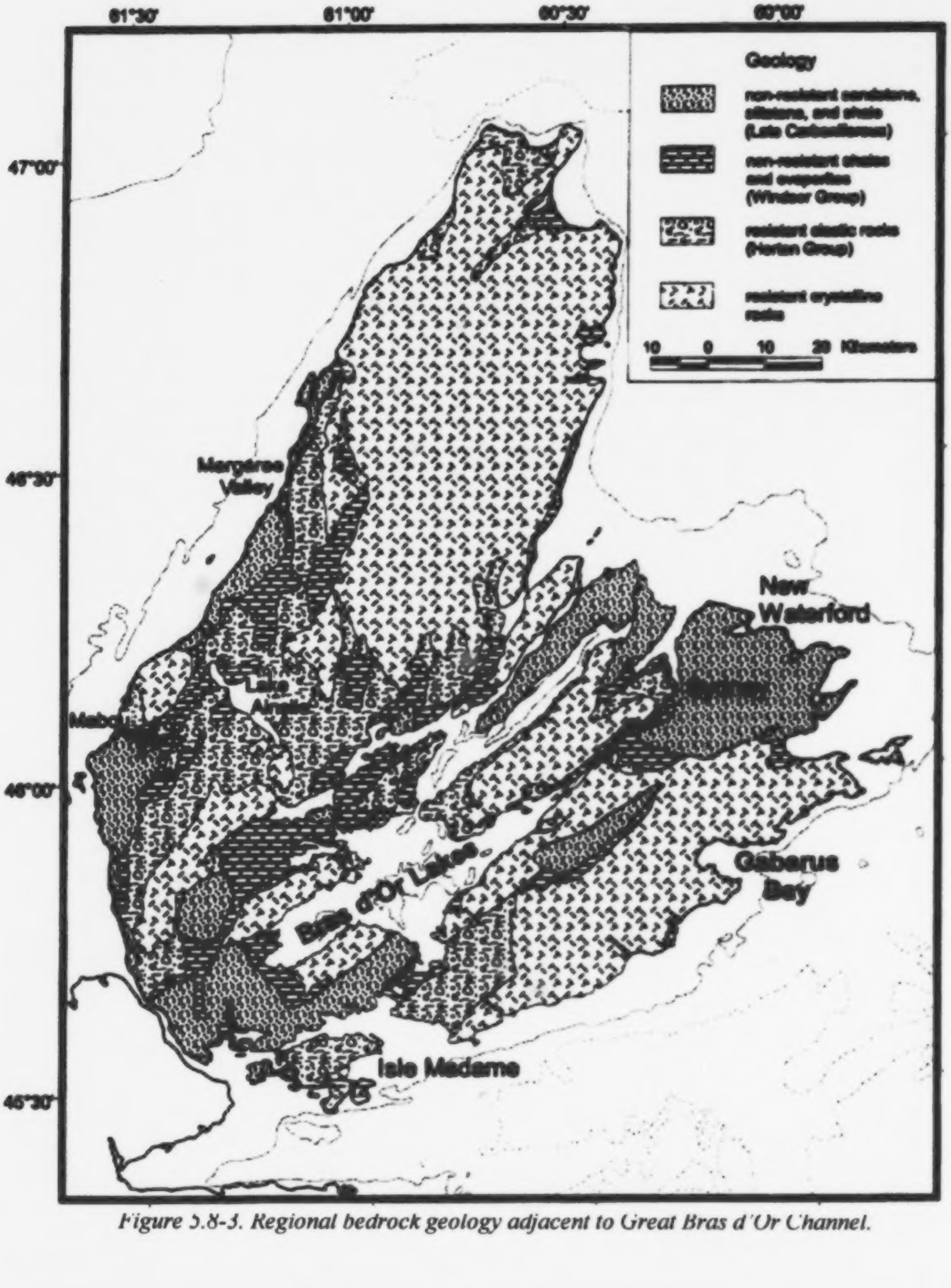
61°30'
61°00'
60°30'
60°00'
47°00'
46°30'
46°00'
45°30'
Geology
non-resistant sandstone, siltstone, and shale (Late Carboniferous)
non-resistant shales and evaporites (Windsor Group)
resistant clastic rocks (Horton Group)
resistant crystalline rocks
10 0 10 20 Kilometers
Margaree Valley
Lake Ainslie
Mabou
New Waterford
Bras d'Or Lakes
Gabarus Bay
Isle Madame

Figure 5.8-3. Regional bedrock geology adjacent to Great Bras d'Or Channel.

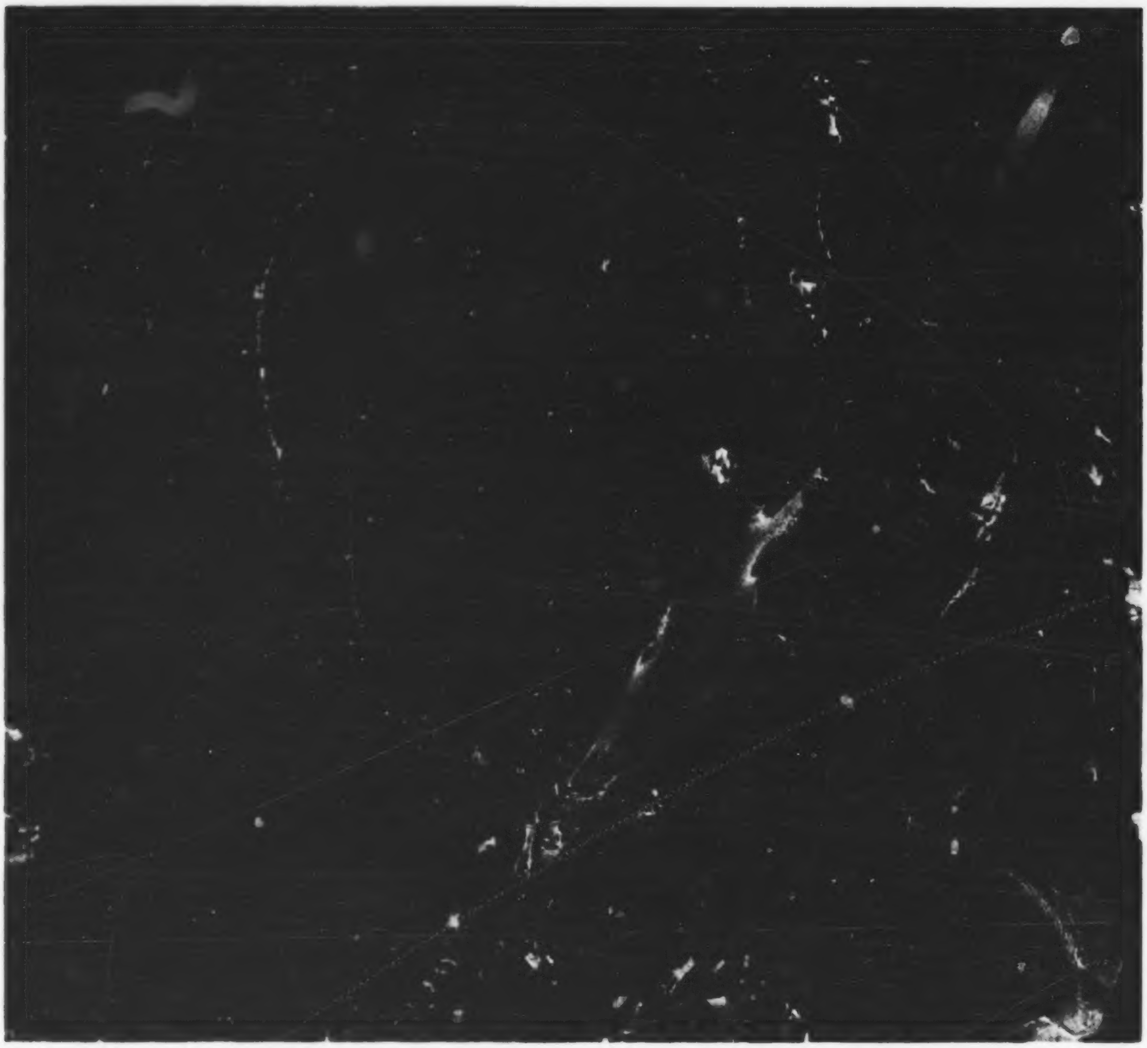

Figure 5.8-4. Multibeam imagery of Great Bras d'Or Channel

5.8.3. *Utility Grid Interconnection*

Interconnection to the NSPI grid is shown in Figure 5.8-7 for 25 kV and Figure 5.8-8 for 69 kV.

Great Bras d'or – supplied by 3S-403
~1KM to water est. ~$60,000
3~4 MW direct
<2 Mw induction
500 meters to channel center

(138KVA if future commercial installation of interest, other issues in transmission from Cape Breton may override further large development.)

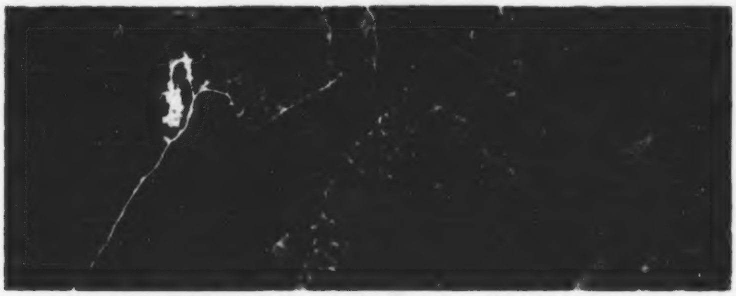

Figure 5.8-5 Distance from Site to 25 kV connection

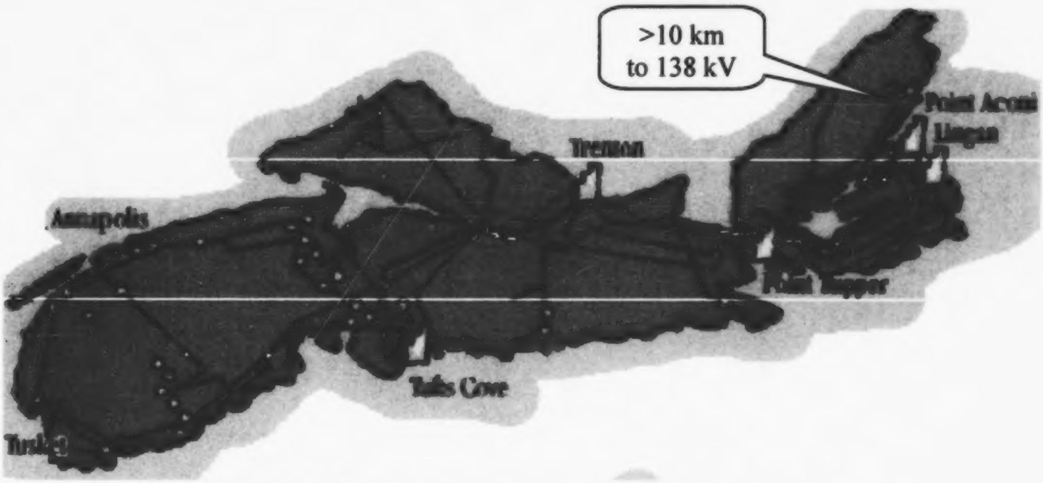
>10 km
to 138 kV
Point Aconi
Lingan
Trenton
Annapolis
Point Tupper
Tufts Cove
Tusket

Figure 5.8-5 Distance from Site to transmission connection

5.8.4. Maritime Support Infrastructure

A moderately extensive maritime support infrastructure exists in Sydney, the principal port on Cape Breton Island. There also are shipbuilders there, and so Sydney might serve as the site for device fabrication and assembly as well as inspection, maintenance, and repair. Appendix B provides information about marine support services and fabricators in Nova Scotia.

5.8.5. Environmental Considerations

The Bras d'Or Lakes are recognized as a sensitive environment and have recently been studied with modern techniques. The aboriginal communities have taken a very active role in both study and management of the region. They are interested in sustainable development of resources and are currently working with many government scientists in a study of the region. The discharge of raw sewage and invasive benthic species are two modern problems.

5.8.6. Unique Opportunities

None identified.

6. References

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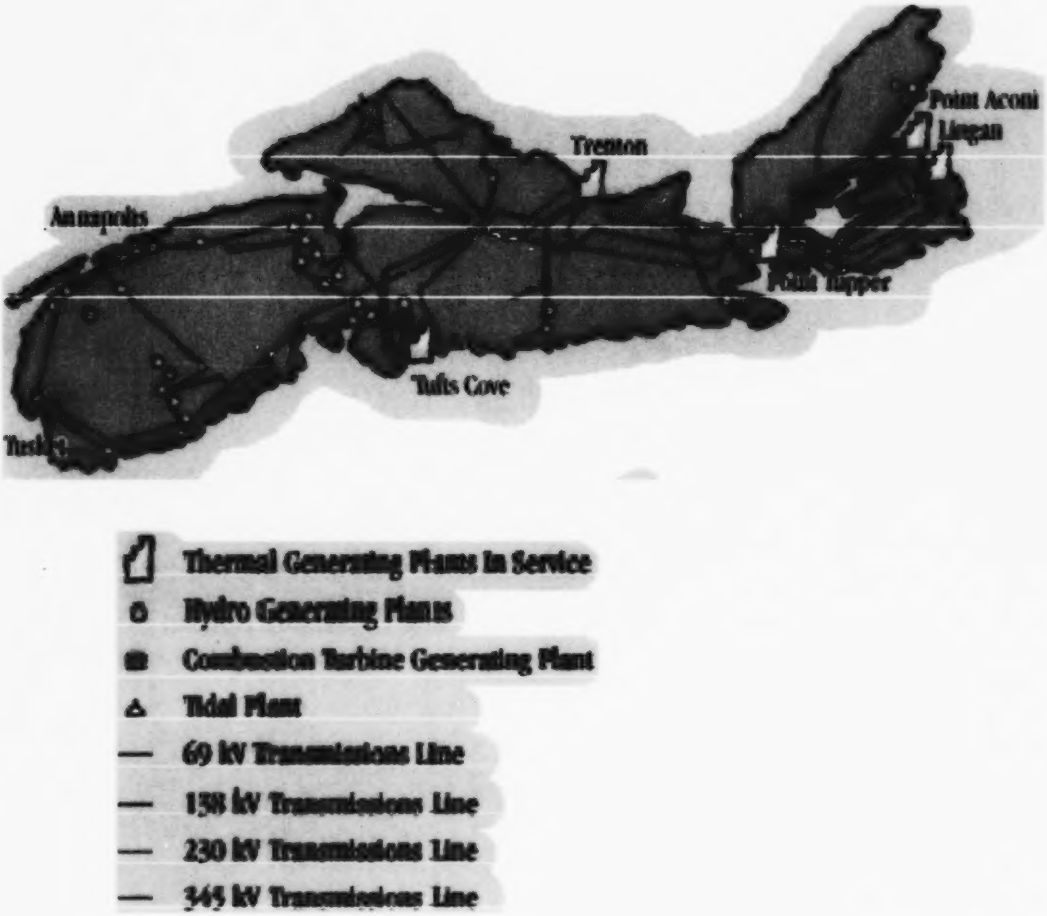
8. Amos, C.L., D.E. Buckley, G.R. Daborn, R.W. Dalyrymple, S.B. McCann, and M.J. Risk, 1980. "Geomorphology and sedimentology of the Bay of Fundy. *Geological Association of Canada Fieldtrip 23 Guidebook.*

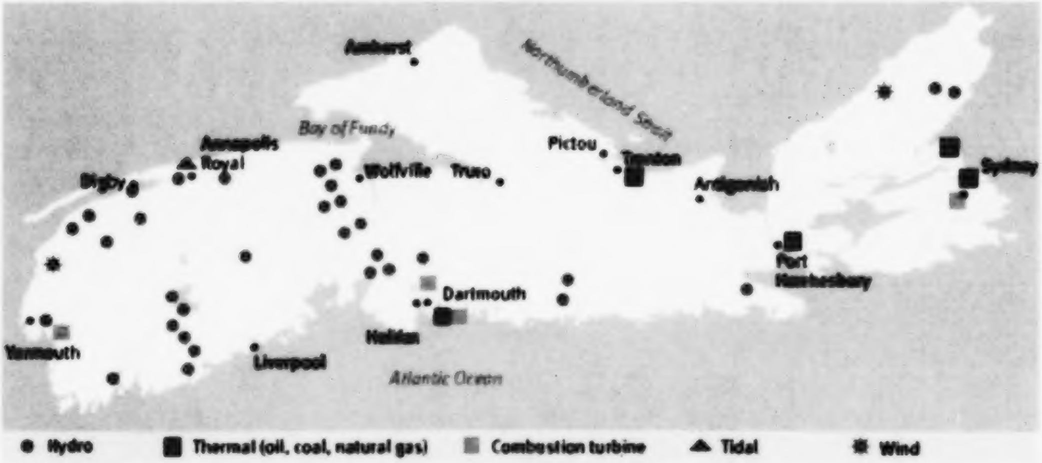
Appendix A

The Nova Scotia Power Inc (NSPI) Grid

This map below shows the NSPI transmission system and also shows the locations of NSPI's five thermal generating stations, 33 hydroelectric plants, the tidal plant and three combustion plants throughout Nova Scotia


Point Aconi
Lingan
Trenton
Annapolis
Point Tupper
Tufts Cove
Tusket
Thermal Generating Plants In Service
○ Hydro Generating Plants
● Combustion Turbine Generating Plant
△ Tidal Plant
— 69 kV Transmissions Line
— 138 kV Transmissions Line
— 230 kV Transmissions Line
— 345 kV Transmissions Line

NSPI's generating fleet also includes an additional combustion turbine site and two wind turbines sites not shown on this dated map above but is shown on a more recent map, which does not show the transmission system, below.


Amherst
Northumberland Strait
Bay of Fundy
Annapolis Royal
Digby
Wolfville
Truro
Pictou
Trenton
Antigonish
Sydney
Port Hawkesbury
Dartmouth
Halifax
Liverpool
Yarmouth
Atlantic Ocean
● Hydro
■ Thermal (oil, coal, natural gas)
■ Combustion turbine
▲ Tidal
✱ Wind

Nova Scotia Power owns and operates over 5,400 km of transmission lines and over 25,000 km of distribution lines within Nova Scotia. NSPI's transmission system consists of more than 200 substations, including major substations at Lingan, Port Hastings, Brushy Hill, Onslow and Woodbine.

NSPI has established an Energy Control Centre (ECC) in the Ragged Lake Industrial Park. This centre uses technology to supply Nova Scotia with electrical services in the most efficient and economical way possible.

The main function of the ECC is to control the generation and transmission of power throughout the Provincial Grid using a highly sophisticated computer system.

On any given day, the ECC monitors power use and responds appropriately. For example, as people use more power when supper hour approaches, adjustments are made in energy output to meet the demand. The ECC provides direct control of all major generating plants throughout the Provincial Transmission Grid Network. Within each power plant, a modern computer control room allows the operator to monitor all phases of the operation.

Generation, transmission and distribution of electricity, purchases and sales of electricity with New Brunswick, and power restoration, are coordinated from a single point, the ECC.

The ECC is a collection point for information from consumers, as well as where the decisions are made and the orders issued. Measurements of all kinds are taken all over Nova Scotia and transmitted to the ECC where enormous quantities of data are continually being gathered, displayed and processed.

One of the most modern computerized control systems in Canada provides Nova Scotia Power operators with around-the-clock service to customers and an updated picture of the entire system. This enables them to allocate generation resources and undertake any necessary switching operations. For example, they can open or close a transmission line or increase or decrease the production at a generating station.

Appendix B

Nova Scotia Shipyards and Industrial Marine Industry

The Shipbuilding and Industrial Marine Industry sector plays an essential part in Canada's economy by designing, building, repairing, maintaining and refitting ships for the marine transportation system[1]. It also supports in a similar way the offshore oil and gas industry and the Government of Canada's naval and coast guard fleets. Despite its importance, and while some parts of the industry are flourishing, the sector as a whole has fallen on hard times in recent years, as witnessed by yard closures, declining employment and lack of orders for new ships.

To a large extent, these problems have not resulted from any lack of technological innovation or productivity on the part of the Canadian industry. Rather, they reflect low labour costs and strong protectionism in other countries, combined with aggressive (even predatory) competition in the form of foreign government subsidies. The difficulties for the Canadian industry have been exacerbated by a growing tendency on the part of the Government of Canada to look offshore for its own marine procurement. At the same time, Canadian ship owners are, by competitive necessity, increasingly price-sensitive when it comes to expanding or replacing their fleets, and government policies have not provided strong enough incentives to offset the attractions of purchasing from foreign yards.

The outcome of this has been a lack of sustained business for many parts of the Shipbuilding and Industrial Marine Industry sector, leading to empty order books, or at best sporadic work. There are important exceptions where the industry enjoys high levels of shipyard activity, notably offshore oil and gas on the East Coast and repair/refit on the West Coast, but these alone are not sufficient to sustain a healthy industry.

The Canadian Shipbuilding and Industrial Marine Industry has strong and innovative technological capacity and a skilled workforce. When it has a reasonably steady flow of orders to which it can apply its capability, the Canadian industry is second to none in the design and building of quality products. The industry recognizes that to be successful in the marketplace it must continue innovating aggressively; at the same time it must build a new generation of skilled workers to continue the tradition from the aging workforce of today. It is ready to continue this investment and it looks to governments to do their part both in terms of generating demand through procurement and fostering competitiveness through an enhanced public policy framework.

Innovation and a skilled workforce are prerequisites to competition. But they can achieve nothing unless the industry has work to do. This means creating an environment in which Canadian firms can compete for Canadian business on reasonably equal terms with offshore industries. Without a continuing domestic demand for its products and services the sector as a whole will decline to a point where no amount of investment in innovation can bring it back. Tidal in-stream device fabrication may represent a new domestic market for Canadian builders.

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[1] "Innovation and Canada's Shipbuilding and Industrial Marine Industry Sector" The Innovation Steering Committee of the Canadian Shipbuilding and Industrial Marine Industry, June 2002

Nova Scotia Shipyards

Nova Scotia contains a number of shipyards that have the capability of fabricating, assembling and deploying in stream tidal energy conversion equipment. These shipyards include:

- A.F. Therault
- Irving
    - Halifax
    - Pictou Industries
    - Woodside
- Lunenburg Industrial Foundry and Engineering
- North Sydney Marine
- Steel and Engine products Ltd

Halifax Marine Industry Infrastructure

Halifax harbor has a very robust marine industry. A list of marine companies is contained below. Their locations in Halifax/Dartmouth are listed below.

Marine Engineering

A. Allswater **Marine** Consultants	3248 Isleville Street, Halifax, NS B3K 3Y5
B. SGE Acres Limited	1009-1809 Barrington Halifax, NS B3J 3K8
C. Canadian **Marine** Consultants Limited	1489 Hollis Street Halifax, NS B3J 3M5
D. Lengkeek Vessel **Engineering** Inc	301-11 Portland Street Dartmouth, NS B2Y 1H1
E. Ship's Aid International Ltd	159 Portland Street Dartmouth, NS B2Y 1H9
F. Yachtsmiths International Inc	2 Maitland Street Dartmouth, NS B2Y 3L7
G. Fleetway Inc	200-155 Chain Lake Drive Halifax, NS B3S 1B3
H. E Y E **Marine** Consultants	327 Prince Albert Road Dartmouth, NS B2Y 1N7
I. Tech **Marine** Limited	50 Thornhill Drive Dartmouth, NS B3B 1S1
J. SNC Lavalin Defence Programs Inc	10 Akerley Boulevard Dartmouth, NS B3B 1J4

Marine Construction

A. Irving Shipbuilding Inc	3099 Barrington St Halifax, NS B3K 1A1
B. SNC-Lavalin Inc	5657 Spring Garden Rd Halifax, NS B3J 1G9
C. AMEC	1874 Brunswick Street Halifax, NS B3J 2G7
D. Allswater **Marine** Consultants	3248 Isleville Street Halifax, NS B3K 3Y5
E. National Research Council	1411 Oxford Street Halifax, NS B3H 3Z1
F. Saiwoo Contracting	1894 Barrington Street Halifax, NS B3J 2A8
G. Yachtsmiths International Inc	2 Maitland Street Dartmouth, NS B2Y 3L7
H. O'Halloran Campbell Consultants Ltd	1657 Bedford Row Halifax, NS B3J 1T1
I. Pro-Dive **Marine** Services	20 Estates Road Dartmouth, NS B2Y 4K7
J. CAD Services Limited	1657 Bedford Row Halifax, NS B3J 1T1

Sydney

Sydney Halifax harbor also has a very robust marine industry. A list of marine companies is contained below. Their locations in Sydney are listed below.

A. Imp Group Ltd	1291 Victoria Rd Sydney, NS B1N 1L7
D. Dillon Consulting Limited	275 Charlotte Street Sydney, NS B1P 1C6.
E. Jacques Whitford	222 George Street Sydney, NS B1P 1J3
F. AMEC	55 Townsend Street Sydney, NS B1P 5C6
G. SGE Acres Ltd	325 Vulcan Avenue Sydney, NS B1P 5X1
H. A D I Limited	70 Crescent Street Sydney, NS B1S 2Z7
I. CBCL Limited	164 Charlotte Street Sydney, NS B1P 1C3

A Canadian government directory of shipbuilding and industrial marine companies is available at http://strategis.ic.gc.ca/cgi-bin/sc_coinf/ccc/index_gen/company.pl?lang=e&profileId=1412_t&tagid=011026

An industry ssociation directory of Nova Scotia boatbuilders is available at http://www.nsboats.com/members.asp